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ORIGINAL ARTICLES.

The Distribution of Scandinavian Boulders in Britain.

By James Phemister.

IN the following pages the writer has attempted to collate the records of boulders of Scandinavian origin which are scattered through many publications. The lists of boulders in Table C of this paper are an amplified version of similar lists drawn up by T. Sheppard[1] in 1895, and, in addition, lists of percentages of various types of boulders are shown in Tables A and B, those in A having been already recorded, while those in B are original. From a study of the statistics set out below the writer has ventured to make certain suggestions with regard to the debated question of the extension of a Scandinavian ice-sheet over Britain.

1. On pp. 440–51 are lists showing details of the occurrence of Scandinavian boulders in Britain. An explanation of abbreviations used in the tables will be found on pp. 453–4. Two notes only are necessary here. First, where altitudes were not given in the original records an approximation was made from Bartholomew's half-inch maps of England. Second, the tables contain records only of igneous rocks with two exceptions, namely, records of sparagmite sandstone and conglomerate, and records, made by geologists intimately acquainted with Scottish schists and gneisses, of metamorphic rocks not recognized by them as Scottish. The sketch-map on p. 435 is a graphical representation of the entries in Table C, each entry being responsible for one cross on the map except where, for reasons of space, generalization was necessary.

2. An analysis of Table C is now given. The numbers indicate number of entries, not number of boulders, and exclude occurrences of sparagmite, hälleflinta, granite, and boulders described merely as "rocks from the Kristiania region".

Norwegian.	Swedish (Dala).	Baltic.
177	12	6

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[1] *Glacialist's Magazine*, vol. iii, 1895–6, opp. p. 136.

The Norwegian rocks are detailed as follows :—

Rhomb-porphyry	96
Laurvikite, augite-syenite, zircon-syenite .	43
Laurdalite, nepheline-syenite, foyaite . .	15
Syenite, nordmarkite	20
Fredriksvärn porphyry	3
	177

The Dalarne rocks include

Red porphyries from Bredvad and Särna .	6
Grönklitt porphyrite	1
Elfdal porphyry	2
Dala porphyry and felsite	3
	12

Rapakivi and Ångermanland granites are the rocks recognized as Baltic. So far no basalt boulders appear to have been claimed as Scanian basalts, though as the latter include nepheline-basalts and -basanites, leucite-basalts and -basanites, their recognition should be possible by extensive microscopic examination.

3. Percentage distribution of igneous and metamorphic rocks in the Yorkshire boulder clay is now considered. No percentage determinations of Scandinavian rocks appear to have been made hitherto, but general analyses have been made at many localities on the Yorkshire coast, and from these general analyses Table A has been compiled. In these determinations only boulders of, or upwards of, a certain diameter—usually one foot—have been considered, the reason being that the larger blocks are thought more likely to indicate the actual origin of the ice, whereas the small pebbles may have been beach pebbles caught up by the ice.[1] It will be shown afterwards, however, that percentages determined on small pebbles give the same results as those determined on large blocks. The writer has made estimations at several localities of the composition of the boulders of the lower boulder clay of the Yorkshire coast and the method used by him was the extraction and registering of every boulder within a marked-out area of the boulder clay cliff. In the determination of the specimens he has had the great advantage of appeal to Dr. H. H. Read, of H.M. Geological Survey, who has an unrivalled knowledge of the porphyries and porphyrites of the Southern Uplands of Scotland. The results of the enumerations are tabulated in Table B, and it will be seen by comparison with Table A that there is no pronounced disagreement between the percentages determined on boulders of all sizes (Table B) and those determined only on large boulders (Table A). Mr. J. W. Stather,[2] however, states that the percentage of far-travelled rocks is higher among the smaller boulders of the boulder clay of East Yorkshire than among the larger ; this does not seem to be borne out by the writer's results.

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[1] G. W. Lamplugh, " Larger Boulders of Flamborough Head," *Proc. Yorks. Geol. Poly. Soc.*, vol. xi, 1888–90, p. 233.

[2] " Sources of Yorkshire Boulders," GEOL. MAG., 1901, p. 19.

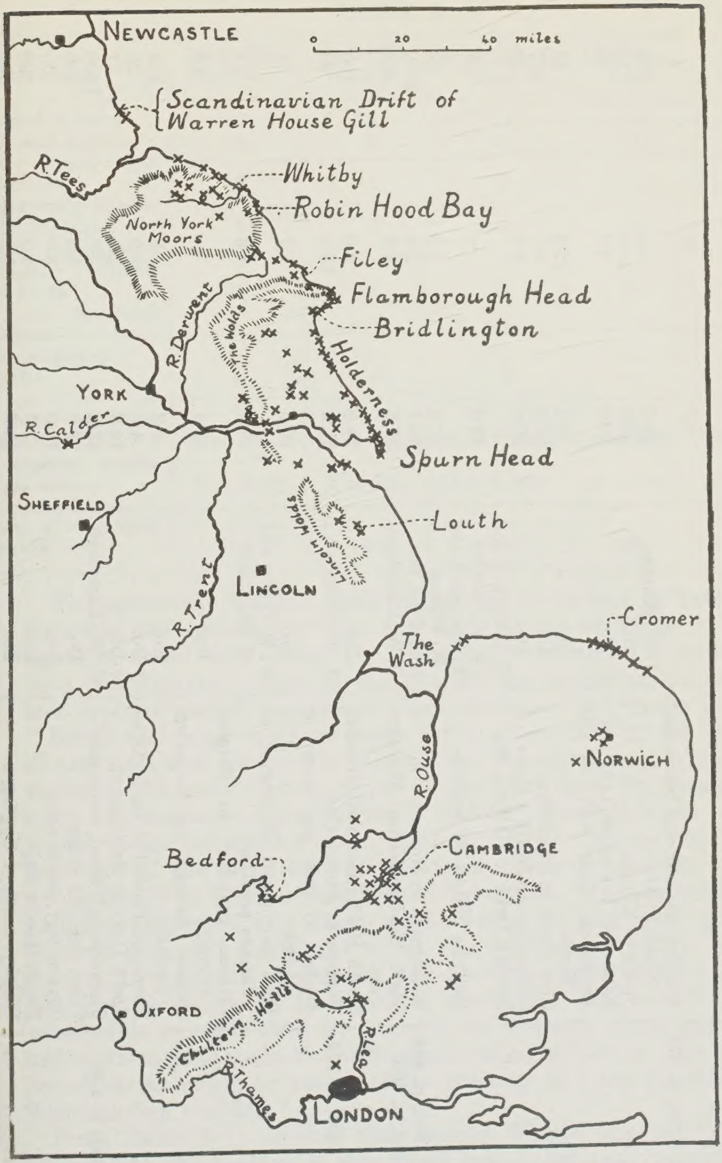

FIG. 1.—Sketch-map showing the Distribution of Scandinavian Boulders in England, prepared from the Tables on pp. 440–51. Each locality in the Tables is shown by a × on the map except where owing to lack of space it has been necessary to generalize.

TABLE A.

Reference.	Locality.	Observer.	Basalt and other eruptive rocks.	Granite, schist, gneiss, etc.	Total number of rocks examined.
			%	%	
B.A. Rep., 1896, p. 373	Boulder clay cliff and beach near North Ferriby	J. W. Stather	23·5	8·5	373
Do.	Spurn to Kilnsea	Do.	40·0	19·9	15
Do.	Kilnsea to Easington Lane end	Do.	20·8	4·2	72
Do.	Easington Lane end to Cliff House	Do.	28·1	12·3	57
Do.	Cliff House to Outnewton	Do.	28·8	9·1	267
Do.	Outnewton to Nevill's Dyke	Do.	20·0	3·3	30
Do.	Nevill's Dyke to Hollyn's Mill	T. Sheppard and J. W. Stather	23·2	—	82
Do.	Hollyn's Mill to Withernsea	T. Sheppard and F. Walton	37·5	1·7	56
B.A. Rep., 1895, p. 434	Withernsea to Hornsea	Hull Geol. Soc.	26·7	3·4	2070
Q.J.G.S., 1891, p. 409	South Holderness near Withernsea	G. W. Lamplugh	37·3	3·4	500
Do.	North Holderness, near Hornsea	Do.	14·0	2·0	100
B.A. Rep., 1896, p. 374	Hornsea to Atwick Gap	J. W. Stather	27·2	13·5	59
Do.	Atwick to first gap north of Atwick	Do.	10·5	1·7	57
Do.	First gap north of Atwick to Skipsea peat-bed.	W. H. Crofts and T. Sheppard	7·8	1·3	77
Do.	Skipsea peat-bed to Skipsea Brough	Do.	2·8	—	36
Do.	Skipsea Brough to Barmston Outfall	Do.	9·2	1·8	163
Do.	Barmston Outfall to Earl's Dyke	Do.	4·0	8·0	25
Do.	Earl's Dyke to Bridlington	Do.	16·2	2·7	37
Q.J.G.S., 1891, p. 409	Flamborough Head, south side	G. W. Lamplugh	43·2	5·7	1100
Do.	Filey, near the Brigg	Do.	19·0	2·0	100
Do.	Cayton Bay, south side	Do.	18·0	3·0	100
Do.	Robin Hood's Bay	Do.	7·0	4·0	100
Do.	Whitby, north of Upgang	Do.	15·5	1·0	200
B.A. Rep., 1896, pp. 373, 375	Redcar to Saltburn	P. Davis and J. W. Stather	15·8	—	133

TABLE B.

Rock-type.	West Cliff Whitby.	East Cliff Whitby.	Robin Hood's Bay.	Carr Naze Filey.	Bridlington South Cliff.
salt and dolerite .	8	1	25	16	41
anite and diorite .	3	4	26	4	5
eiss, schist, and epidiorite . .	2	1	4	1	6
tamorphic grit, probably Highland .	1	1	—	2	3
desite, felsite, and Southern Upland dyke-rocks . .	16	11	37	18	42
uth of Scotland sediments . .	14	1	10	7	15
omb-porphyry .	—	—	—	—	3
urvikite . .	—	—	1	—	—
tal basalt and other eruptive rocks .	24 = 8%	12 = 12%	62 = 12·4%	34 = 17%	86 = 21·5%
tal granite, schist, gneiss, etc. . .	5 = 1·7%	5 = 5%	31 = 6·2%	5 = 2·5%	11 = 2·75%
mber of boulders collected . .	303	100	500	202	400

The agreement between Table A and the lower part of Table B indicates the probability that the large groups of Table A will agree in detail with Table B. Whether to attribute a Scottish or a Scandinavian origin to the granites and metamorphic rocks is a problem almost hopeless of direct solution. But in the group "Basalt and other eruptive rocks" it is a fact that all the types of andesites and porphyrites collected by the writer can be closely matched either by Cheviot types or by types from the immense suite of Southern Upland dykes. Professor Kendall noted with regard to the porphyrites of Robin Hood's Bay[1] that the majority were not of the usual red Cheviot type. This is true, but they are distinctly of the Southern Upland dyke type. The sedimentary boulders associated with them are for the most part grey, green, and red grits and sandstones which can be matched in the greywackes, Downtonian sandstones, and grey-green grits of the Lower Old Red Sandstone of the south of Scotland. It is therefore as permissible to argue that, by analogy, the majority of the granites and metamorphic rocks are of Scottish origin, as it is to urge their Scandinavian origin by reason of the presence of a few identifiable Scandinavian boulders.[2]

From Table B it appears that around Whitby the percentage of Scandinavian boulders is very small indeed, but that it increases southwards till it is as high as 0·75 at Bridlington. (See below.)

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[1] *B.A. Report*, 1908, p. 243.

[2] G. W. Lamplugh and A. Harker, "Drifts of Flamborough Head," *Q.J.G.S.*, vol. xlvii, 1891, pp. 409–10.

For reference, the composition of a real Scandinavian boulder clay discovered by Dr. C. T. Trechmann at Warren House Gill, Durham, is given in the following table:—

Gneisses, very various	24·3
Hornblende-gneisses and schists	7·3
Green and grey mica-schists, "Glimmerschiefer," green schists, etc.	10·0
Granites, very various	2·6
Red and grey syenites (nordmarkites) often visibly titaniferous	1·3
Augite-syenite (laurvikite)	7·9
Rhomb-porphyry	5·7
Rhomb-porphyry conglomerate	0·5
Red and brown porphyry, no macroscopic quartz	6·5
"rhyolitic porphyries"	9·4
Various quartzites	10·5
Quartz-pebbles, vein stuff	5·2
Dark porphyritic rocks apparently derived from intrusions	1·0
Doubtful crystalline rocks	1·9
Limestones, not Permian	0·5
Flint and Chalk	4·4
Sandstones	1·0
	100·0

One-eighth of the collection is represented by rhomb-porphyry and laurvikite. Using this as a standard we may then reckon that the total percentage of Scandinavian rocks in the boulder clay of Bridlington is of the order 6 per cent. The total percentage of igneous and metamorphic rocks is, however, 24·25 per cent. It seems justifiable to conclude, therefore, that the lower boulder clay of Yorkshire has a pronounced Scottish character with a subordinate but still marked Scandinavian bias.

4. The increase in the proportion of Scandinavian rocks from north to south along the east coast of England has long been recognized. H. Carvill Lewis[1] states that the proportion is much greater near Louth in north-east Lincolnshire than it is in Holderness. Though the figures are too low to be a really reliable guide Table B indicates that Scandinavian boulders become commoner towards the south of Yorkshire. The southerly increase is, however, shown by the following figures for igneous boulders (exclusive of basalts) collected by the writer from the beach at several localities.

	Whitby.	Robin Hood's Bay.	Filey.	Bridlington.
Rhomb-porphyry and laurvikite	0	2	2	7
Total examined	21	58	36	50

Mr. J. W. Stather[2] has tabulated the relative proportions of groups of far-travelled rocks for various localities in Yorkshire and shows how the proportion of the group "granite, gneiss, etc." increases southwards. He attributes this relative increase to the incoming of the Scandinavian rocks. Tables A and B show that the actual percentage of "granite, gneiss, etc." is variable, and does not show any definite increase southwards; the relative increase shown by Mr. Stather may therefore be due to decrease in the less far-travelled boulders—the Carboniferous and Permian sediments. His further point that Shap granite becomes less abundant southwards, is, however, suggestive as indicating the increase of some other group—probably the Scandinavian—in this direction. No estimations of the relative abundance of non-British rocks in Lincolnshire or Norfolk appear to have been made, but it is known Norwegian rocks are decidedly abundant on the Norfolk coast. It cannot, therefore, be definitely stated that the southward increase continues beyond Lincolnshire.

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[1] *Glacial Geology of Great Britain and Ireland*, 1894, p. 234.
[2] "Sources of Yorkshire Boulders," Geol. Mag., 1901, p. 19.

5. Reference has already been made to a real Scandinavian boulder clay. This is described in detail by Dr. Trechmann.[1] It occurs in a pre-glacial depression at Warren House Gill on the Durham coast, and is overlain by the main (Cheviot) drift. The analysis of its boulders has already been reproduced on p. 438. Broken shells are common and Trechmann notes that the fauna rather closely resembles that of the transported shell-beds in the Basement Clay at Flamborough South Landing. That this boulder clay was actually deposited by the fringe of the Scandinavian ice-sheet is a view to which Dr. Trechmann was strongly inclined, but he did not rule out the possibility that the Scandinavian stones in it may have been dropped close to the English coast and subsequently incorporated in another ice-sheet which filled the basin of the North Sea, but was not necessarily Scandinavian. At any rate it seems unlikely to have been deposited by any ice-sheet which had its origin in Britain. Mr. Lamplugh [2] claimed this boulder clay as the equivalent of the Basement Clay of Yorkshire, but Trechmann, in a subsequent paper,[3] does not regard this correlation as certain, and from a comparison of the lists of boulders of the two clays which have been given above (pp. 436 and 438) it seems clear that Trechmann is justified in his disinclination to accept Lamplugh's view. If this be so, then it follows that there is no real Scandinavian boulder clay in Yorkshire, for Lamplugh's detailed work makes it perfectly clear that the Basement Clay is the oldest boulder clay in the Flamborough district.[4] The sections examined by him in the depressions and deep hollows of the Chalk at Flamborough are exactly the places in which, by analogy with the Durham exposures, we should expect to find the Scandinavian clay, yet in these hollows the Basement Clay rests directly on Chalk rubble and pre-glacial gravels. It is interesting to note that, qualitatively,

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[1] "Scandinavian Drift of the Durham Coast," *Q.J.G.S.*, vol. lxxi, 1915, p. 53.

[2] In the discussion on Trechmann's paper, *Q.J.G.S.*, vol. lxxi, 1915, p. 80.

[3] "Deposit of Interglacial Loess, etc.," *Q.J.G.S.*, vol. lxxv, p. 185.

[4] "The Drifts of Flamborough Head," *Q.J.G.S.*, vol. xlvii, 1891, pp. 384–429, particularly pp. 416–17.

TABLE C.

Locality.	Altitude (feet).	Rock-type.	Mode of Occurrence.	Reference and Notes.
SCOTLAND.				
Dalsetter, Dunrossness, Shetland.	100	Tönsbergite . .	In B. Cl. . .	T. M. Finlay, *Proc. Edin. Geol. Soc.*, Jan., 1926. Boulder over 2 tons in weight.
East shore of Flotta, Orkney Islands.	—	Ld. . . .	On shore . .	W. I. Saxton and A. T. Hopwood, GEOL. MAG., 1919, p. 273. Identified by Sir J. S. Flett.
Sanday, Orkney Islands.	—	Biotite-gneiss with orthite . .	Large erratic .	Sir J. S. Flett, GEOL. MAG., 1898, p. 391.
Portsoy, Banffshire . .	—	Rh. P.	On shore . .	H. H. Read, " Geology of Banff, etc.," *Mem. Geol. Surv.*, 1923, p. 203. Rounded boulder, 11 in. × 9 in. × 6 in.
Bay of Nigg, Aberdeen . .	15	Rh. P. . .	In fluvioglacial deposit beneath Lower Grey B. Cl.	A. Bremner, *Trans. Edin. Geol. Soc.*, vol. xi, 1923, p. 230. Associated with boulders common in the drift of the lower Dee Valley. Weight 32 lb.
Arnage, Aberdeenshire . .	—	Rh. P. . .	In B. Cl. . .	R. Campbell, *Trans. Edin. Geol. Soc.*, vol. xi, 1923, p. 230.
Ellon, Aberdeenshire . .	—	Lv. . . .	—	A. W. Gibb, *Trans. Edin. Geol. Soc.*, vol. xi, 1923, p. 230. Two boulders, one built into wall of a house, the other collected by the late Professor James Nicol.
NORTHUMBERLAND.				
Tynemouth and Lyne Burn .	—	Howse's Scandinavian Drift with flints.		J. A. Smythe, *Trans. Nat. Hist. Soc. North*, vol. iv, new series, 1912. C. T. Trechmann, *Q.J.G.S.*, 1915, p. 54, notes that the lower drift contains Cheviot and Lake District boulders, but no trace of Scandinavian rocks. Definitely rejects (p. 81) the flints as Scandinavian as they do not agree with the dark splintery flints found in the Scandinavian B. Cl. of Warren House Gill (*see below*).

Locality.	Altitude (feet).	Rock-type.	Mode of Occurrence.	Reference and Notes.
DURHAM.				
Cleadon	100	Black flints	In raised beach	D. Woolacott, *B.A. Rep.*, 1909, p. 71.
Do.	—	Syenites of doubtful origin.	Gravel	G. Weyman, *B.A. Rep.*, 1910, p. 102.
Warren House Gill[1]	—	Lv.; Rh. P.; Rh. P.-conglom.; Red P.; broken shells.	In B. Cl. in sea-cliff.	C. T. Trechmann, *Q.J.G.S.*, 1915, pp. 61–9. Some are large, most small; some well polished and striated, some rounded and waterworn. He regards all the boulders as Scandinavian. No Baltic or Swedish rocks present.
1 mile N. of Castle Eden	—	Lv.	Cemented into Magnesian Lst. on beach.	D. Woolacott and G. T. Mackay, *B.A. Rep.*, 1911, p. 103.
Castle Eden Dene	—	Lv.	From foundations of bridge over the dene.	A. Ball, *B.A. Rep.*, 1911, p. 103.
1 mile S. of Blackhall Rocks, Castle Eden.	—	Lv.	On shore	C. T. Trechmann, *Q.J.G.S.*, 1915, p. 66. Two big boulders not traced to position in situ.
YORKSHIRE.				
Saltburn	—	Lv.; Rh. P.	On beach	P. F. Kendall, *Nat.*, 1898, p. 353.
Staithes	—	Rh. P.	On beach	Do.
Kettleness	—	Ne. Sy.	On beach	E. Hawkesworth, *B.A. Rep.*, 1901, p. 286.
Commondale	560	? Spar.	—	P. F. Kendall and H. B. Muff, *B.A. Rep.*, 1899, p. 401.
Whitby	—	Ne. Sy.	On beach	P. F. Kendall and H. B. Muff, *B.A. Rep.*, 1899, p. 402.

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[1] C. T. Trechmann (*Q.J.G.S.*, 1919, pp. 178–81) states that the upper surface of the Scandinavian B. Cl. is contorted by later ice. Also (p. 185) that he does not think it certain that the Scandinavian B. Cl. of Warren House Gill is the equivalent of the Basement Clay of Holderness as in the latter Scottish and English rocks are mixed up with the Norwegian.

Locality.	Altitude (feet).	Rock-type.	Mode of Occurrence.	Reference and Notes.
YORKSHIRE (*continued*).				
Whitby	—	Bred. P.	—	J. E. A. Whealler, GEOL. MAG., 1921, p. 203.
Danby	625	Rh. P.	—	P. F. Kendall and H. B. Muff, *B.A. Rep.*, 1899, p. 401.
Seavy Slack	700	Rh. P.	—	Do. Do., p. 401.
Stump Howe	650	Rh. P.	—	J. W. Stather, *B.A. Rep.*, 1900, p. 346.
Goathland	480	? Spar.	In red B. Cl.	P. F. Kendall and H. B. Muff, *B.A. Rep.*, 1899, p. 400.
Lealholm	625	Elf. P.; Spar.	" In quarry "	Do. Do. p. 400.
Stonegate	560	? Spar.	—	Do. Do. p. 401.
Do.	—	Alkali dyke-rock from Kristiania region.	—	P. F. Kendall and H. B. Muff, *B.A. Rep.*, 1903, p. 234. Identified by Professor W. C. Brögger.
West Rigg	810	Rh. P.	In B. Cl.	J. W. Stather, *B.A. Rep.*, 1899, pp. 398, 401.
Robin Hood's Bay [2]	Variable.	Rh. P.; Lv.; Frdvn. P.	On beach, washed out of B. Cl.	T. Sheppard and H. B. Muff, *Nat.*, 1897, p. 63. Several Rh. P., largest 12 in. × 10 in. and 7 in. × 6 in.; several Lv., largest 4½ in. × 3½ in.; Frdvn. P., 8 in. × 5 in.
Peak	600	Rh. P.	Glacial Gravel	J. W. Stather, *B.A. Rep.*, 1900, p. 345. Four small boulders.
Ravenscar Station	650	? Elf. P.; ? Spar.	Gravel	P. F. Kendall and H. B. Muff, *B.A. Rep.*, 1899, p. 401.
Kirkmoorgate	600	Rh. P.	—	J. W. Stather, *B. A. Rep.*, 1900, p. 345. 7 in. × 4 in. × 4 in. and two small pebbles.
Filey (Carr Naze)	50–100	Ne. Sy.	In B. Cl.	J. W. Stather, *B.A. Rep.*, 1899, p. 399. Two pebbles, 3 in. to 4 in. in diameter.
Filey [3]	—	Rh. P.	From brickfield	J. W. Stather, *B.A. Rep.*, 1899, p. 400. Two specimens.

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[2] T. Sheppard and H. B. Muff, " Glacial Geology of Robin Hood's Bay," *Glac. Mag.*, 1896–7, p. 50, state: " With regard to the Norwegian erratics, these are usually, though not always, in small pebbles, well-rounded and having no flaws or cracks. They are occasionally ice-scratched, and in some cases have a beautiful ' sole '."

[3] On the beach at Filey the writer picked up a rounded pebble, 1 in. in diameter, of red porphyritic essexite, which, in the hand, is unlike any of the Scottish essexites, and is probably of Norwegian origin.

Locality.	Altitude (feet).	Rock-type.	Mode of Occurrence.	Reference and Notes.
YORKSHIRE (*continued*).				
Ayton	250 +	Rh. P.	—	Boulder Committee Hull Geol. Soc., *B.A. Rep.*, 1901, p. 287.
Wykeham	100	? Ne. Sy.	In gravel	E. Hawkesworth, *B.A. Rep.*, 1901, p. 287. Small pebble.
Seamer	100	Rh. P.	In glacial gravel	Boulder Committee Hull Geol. Soc., *B.A. Rep.*, 1901, p. 287.
Hutton Bushel	120	Rh. P.	Gravel	Do. Do. Do.
Gristhorpe	—	Rh. P.; Åug. Gr.	On beach	J. W. Stather, *B.A. Rep.*, 1899, p. 400.
Speeton	400	Rh. P.	In moraine	Do. Do. Do.
Do.	—	Rh. P.	High up on the cliffs.	H. Carvill Lewis, *Glacial Geology of Great Britain and Ireland*, 1894, p. 211.
Thornwick Bay	—	Lv.	—	J. W. Stather, *B.A. Rep.*, 1899, p. 400; 4 in. × 3 in. × 3 in.
Flambro	—	Rh. P.	In brickfield	J. W. Stather, *B.A. Rep.*, 1899, p. 400.
Bridlington, Dimlington, and High Stacks.	—	Aug. Sy.; Saussurite-gabbro	In Basement Clay	G. W. Lamplugh and A. Harker, *Proc. Yorks. Geol. Soc.*, 1889, pp. 298, 303–4, pp. 410–12. Various sizes.
Bridlington	—	Black and red flints and metamorphic rocks.	In Basement Clay	C. Reid, "Geol. of Holderness," *Mem. Geol. Surv.*, 1885, p. 18. Flints supposed to be Danish.[4]
Do.	—	Lv.	Do.	A. Harker, GEOL. MAG., 1894, p. 334.
Rudstone	90	Rh. P.	In gravel	J. W. Stather, *B.A. Rep.*, 1899, p. 400. 3 in. in diameter. Found in the "Gipsy Gravels" with small boulders of the usual Holderness type.
Bessingby	125	Rh. P.	In B. Cl.	J. W. Stather, *Nat.*, 1895, p. 344, and *Glac. Mag.*, 1895–6, opp. p. 136. Two small boulders.
Garton-on-Wolds	150–200	Rh. P.	—	J. W. Stather, *B.A. Rep.*, 1899, p. 400. Two small boulders from Craike Quarry.

Mr. A. Jesson of the Danish Geological Survey states that pink flints do not occur in either the Cretaceous rocks or the drifts of Denmark (note from *B.A. Rep.*, 1899, p. 400).

Locality.	Altitude (feet).	Rock-type.	Mode of Occurrence.	Reference and Notes.
YORKSHIRE (*continued*).				
Driffield	70	Rh. P.	—	E. Maule Cole, *B.A. Rep.*, 1902, p. 255. From Highfield Quarry.
Barmston	—	Rh. P.	In B. Cl.	T. Sheppard, *Glac. Mag.*, 1895–6, opp. p. 136.
Brigham Hill	50	Rh. P.	—	F. F. Walton, *B.A. Rep.*, 1899, p. 399.
Brandesburton	25	Rh. P.	—	J. W. Stather, *B.A. Rep.*, 1899, p. 400. Two pebbles, each about 3 in. diameter.
Brandesburton (Coney Garth)	35	Rh. P.	In gravel	F. F. Walton, *B.A. Rep.*, 1899, p. 399; 6 in. diameter.
Do.		Rh. P.	In gravel.	J. Phemister, GEOL. MAG., 1922, p. 324; two rounded pebbles 3 in. diameter.
Market Weighton	85	Black flints with *Echinocorys vulgaris*.[5]	In gravel	P. F. Kendall, *B.A. Rep.*, 1898, pp. 552, 554.
Atwick	40	Rh. P.; Lv.	At foot of cliff	J. W. Stather, *B.A. Rep.*, 1900, p. 345; several pebbles of Rh. P.; Lv. 18 in. × 18 in. × 12 in.
Skipsea	10	Rh. P.	In B. Cl.	T. Sheppard, *Glac. Mag.*, 1895–6, opp. p. 136; small boulders.
Catwick	50	Rh. P.	In gravel	P. F. Kendall, *Glac. Mag.*, 1895–6, opp. p. 136; 4 in.
Atwick—Hornsea	—	Rh. P.; Lv.	—	J. W. Stather, *Nat.*, 1897, p. 71; Lv. 2 ft. × 1½ ft. × 1 ft. on beach; Rh. P. in place in B. Cl. Also *B.A. Rep.*, 1896, p. 374.
Hornsea	20–30	Amyg. Rh. P.	—	F. F. Walton, *B.A. Rep.*, 1902, p. 256.
Do.	Do.	Black flints [5]	In B. Cl.	J. R. Mortimer, *Glac. Mag.*, 1895–6, opp. p. 136.
Garton	45	Rh. P.	On surface	T. Sheppard, *B.A. Rep.*, 1898, p. 555.
Tunstall	10	Rh. P.	—	T. Sheppard, *Glac. Mag.*, 1895–6, opp. p. 136.
Withernsea	Coast.	Rh. P.; Aug. Sy.	In B. Cl.	Yorks. Nat. Union. *Trans. Leeds Geol. Soc.*, 1892–3, p. 52, quoted from *Glac. Mag.*, 1895–6, opp. p. 136.
Do.	Coast.	Black flints with [5] echinoderms and *Bel. lanceolata*.	—	T. Sheppard, *B.A. Rep.*, 1898, p. 555, and 1908, p. 243.

Locality.	Altitude (feet).	Rock-type.	Mode of Occurrence.	Reference and Notes.
YORKSHIRE (*continued*).				
Out Newton	50	Rh. P.; Lv.; ? Ne. Sy.	—	P. F. Kendall, *B.A. Rep.*, 1895, p. 430; Lv. 2 ft. diameter on the beach.
Easington	20	Ång. Gr.	—	W. H. Crofts, *B.A. Rep.*, 1898, p. 552.
Do.	—	Rh. P.; black and pink flints.[5]	On beach	T. Sheppard, *B.A. Rep.*, 1898, p. 553.
Do.	—	*Bel. lanceolata*[5]	—	J. W. Stather, *B.A. Rep.*, 1898, p. 554.
Do.	—	Danish chalk with flints.[5]	On beach	J. R. Mortimer, *Glac. Mag.*, 1895–6, opp. p. 136, 30–50 yards long.
Cliff House to Out Newton	—	Lv.	On beach	J. W. Stather, *Nat.*, 1897, p. 71; 2 ft. diam.
Dimlington	—	Ång. Gr.; Zr. Sy.	—	Do. *B.A. Rep.*, 1902, p. 256; Ång. Gr., 10 in. × 5 in. × 5 in.; two small boulders of Zr. Sy.
Do.	—	Lv.; Rh. P.	In Basement B. Cl.	T. Sheppard, *B.A. Rep.*, 1898, p. 555.
Do.	—	Qz. Rh. P.	—	Do. *B.A. Rep.*, 1908, p. 243.
Do.	—	Ld.	On beach	A. Harker, GEOL. MAG., 1894, p. 477.
Holderness Coast	—	Lv.; Rh. P.; Saus. Gabbro.	In B. Cl.	A. Harker, GEOL. MAG., 1893, p. 140. *Also* metamorphic rocks.
Do.	—	Ång. Gr.; Häll.,	In B. Cl.	J. W. Stather, *Nat.*, 1898, p. 353. Identified by Dr. Munthe.
Do.	—	Rap. Gr.	—	C. T. Trechmann, *Q.J.G.S.*, 1915, p. 66.
Do.	—	*Bel. lanceolata*	In B. Cl.	J. W. Stather, *Nat.*, 1898, p. 353. Identified by Jukes-Browne.
Spurn to Easington	—	Lv.	In B. Cl.	J. W. Stather, *B.A. Rep.*, 1896, p. 374. Several boulders. Also two blocks 15 in. diam. and thirty small boulders on shore.
Spurn to Kilnsea	—	Lv.	In B. Cl. and on beach.	J. W. Stather, *Nat.*, 1897, p. 71.
Burstwick	50	Rh. P.	In gravel	T. Sheppard, *Glac. Mag.*, 1895–6, table opp. p. 136; also *Nat.*, 1895, p. 343; more or less waterworn; 6 in. × 6 in. × 5 in., 6 in. × 4 in.

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[5] Black flints are unknown in the local chalk and *Bel. lancolata* is also unknown, *B.A. Rep.*, 1898, p. 552. *See also* footnote 4, p. 443.

Locality.	Altitude (feet).	Rock-type.	Mode of Occurrence.	Reference and Notes.
YORKSHIRE (*continued*).				
Burstwick	50	Black and pink flints	In gravel	T. Sheppard, *Glac. Mag.*, 1895–6; table opp. p. 136; supposed Danish, see footnote, p. 443.
Do.	50	Lv.	On surface	W. H. Crofts, *Glac. Mag.*, 1895–6, table opp. p. 136; 5 in. × 4 in. × 3 in.
Do.	—	Foyaite from Kvelle	—	J. W. Stather, *B.A. Rep.*, 1902, p. 256; 5 in. × 4 in × 4 in.; identified by W. C. Brögger.
Newbald	145	Red Granite	On surface	F. F. Walton, *Glac. Mag.*, 1895–6, table opp. p. 136; 13 in. × 9 in. × 5 in.
Swine	10	Rh. P.	In B. Cl.	T. Sheppard, *Glac. Mag.*, 1895–6, table opp. p. 136; 4 in. × 5 in.
Willerby	50	Rh. P.; black flints and *Bel. lanceolata*	—	H. Sales, *B.A. Rep.*, 1898, p. 554.
Wawne	20	Lv.; Rh. P.; black and pink flints.	—	J. F. Robinson, *B.A. Rep.*, 1902, p. 256.
Meaux	10–20	Rh. P.	—	T. Sheppard, *B.A. Rep.*, 1902, p. 256; pebbles.
Do.	—	Rh. P.	—	Do., *B. A. Rep.*, 1901, p. 286.
Ferriby Common	? 100	Rh. P.	In chalky gravel	J. W. Stather, *B.A. Rep.*, 1901, p. 288.
Ferriby (North)	10	Rh. P.; Aug. Sy.; Red. Gr.; Sch.	In lower B. Cl.	J. W. Stather, *Glac. Mag.*, 1895–6, table opp. p. 136; vary in size from large boulders to pebbles.
Brantingham Thorpe	—	Rh. P.	In sandhill	W. H. Crofts, *B.A. Rep.*, 1899, p. 399; 3 in. × 2 in. × 2 in.
Keyingham	50	Rh. P.; black and pink flints.	In B. Cl.	T. Sheppard, *Glac. Mag.*, 1895–6, table opp. p. 136.
Elloughton	100	Lv.	In gravel.	J. W. Stather, *B.A. Rep.*, 1899, p. 399; 18 in. × 15 in. × 12 in.
Brough	100	Rh. P.	In Mill Hill gravel	T. Sheppard, *B.A. Rep.*, 1898, p. 554.
Melton	100	Lv.; Rh. P.	In B. Cl.	J. W. Stather, *Nat.*, 1895, p. 343; identified by A. Harker.
Horbury	150	Rh. P.	—	W. G. Fearnsides, *B.A. Rep.*, 1901., p. 286. Taken up by scoop along with basal clay in excavating for pier of bridge over R. Calder.
South Yorks Coast	—	Rap. Gr.	—	C. T. Trechmann, *Q.J.G.S.*, 1915, p. 66; common.

Locality.	Altitude (feet).	Rock-type.	Mode of Occurrence.	Reference and Notes.
LINCOLNSHIRE.				
South Ferriby	Coast.	Rh. P.	In B. Cl.	Rev. W. Tuckwell, *B.A. Rep.*, 1896, p. 369. Two boulders.
Scunthorpe	130	Ne. Sy.	—	A. C. Dalton, *B.A. Rep.*, 1909, p. 169.
Great Coates	20	Rh. P.	In heap of pebbles	J. W. Stather, *B.A. Rep.*, 1898, p. 356.
Cleethorpes	Coast.	Rh. P.; Ne. Sy	In B. Cl.	P. Davis and J. W. Stather, *B.A. Rep.*, 1901, p. 285.
Do.	Do.	Rh. P.; Häll; red flint, red porph. Gr.	In B. Cl.	H. Carvill Lewis, *Glacial Geology of Great Britain and Ireland*, p. 27, and p. 236. Pebbles and striated boulders.
Welton—Louth	?	Sy.; Gabbro; Sch.; Norite.	—	H. Carvill Lewis, *op. cit.*, p. 234.
Louth	100	Rh. P.; Aug. Sy.	In lower B. Cl.	T. Sheppard, *Nat.*, 1896, p. 336. Rh. P. in plenty. Aug. Sy., 2 ft. × 1 ft. 8 in. × 1 ft. 5 in., scratched.
Do. Chalkpit	—	Rh. P.; Aug. Sy.	—	Rev. W. Tuckwell, *B.A. Rep.*, 1896, p. 368.
Do. Brickyard	—	Rh. P.; Aug. Sy; Frdvn. P.; Häll.	—	Do. Do. Do. Associated with schists, flints, lavas, diorite, millstone grit, carboniferous limestone and sandstone, ironstone.
Do.	—	Lv.; Rh. P.	In B. Cl.	J. W. Stather, *B.A. Rep.*, 1897, p. 350; associated with Mountain Limestone, etc.
Do.	—	Basic rock from Hitterdal.	—	J. W. Stather, *B.A. Rep.*, 1898, p. 555; identified by Professor W. C. Brögger.
Do.	—	Aug. Sy.; Act. Sch.; P.; Gr.;	On surface	H. Carvill Lewis, *op. cit.*, p. 233.
Benniworth	300	Aug. Sy.	—	Rev. W. Tuckwell, *B.A. Rep.*, 1896, p. 349.
Kirmington	60	Rh. P.	In B. Cl.	Rev. W. Tuckwell, *B.A. Rep.*, 1896, p. 370.
Grimsby	Coast.	Grey Gr.; gneissose grey Gr.; coarse red Sy.	—	Rev. W. Tuckwell, *B.A. Rep.*, 1895, p. 428; probably not British.

Locality.	Altitude (feet).	Rock-type.	Mode of Occurrence.	Reference and Notes.
Grimsby	—	Rh. P.; Pt.; Häll.	In B. Cl. . .	C. Reid, "Geology of Holderness," *Mem. Geol. Surv.*, 1885, p. 41.
Do.	—	Rh. P.; Häll.; Danish flint.		C. Reid, "Geology of parts of N. Lincolnshire and S. Yorkshire," *Mem. Geol. Surv.*, 1890, p. 170.
Do.	—	Scand. rocks from Kristiania	10 ft. 15 in. from surface.	Rev. W. Tuckwell, *B.A. Rep.*, 1895, p. 431.
NORFOLK.				
Hunstanton	Coast.	Rh. P. . .	—	R. H. Rastall and J. Romanes, *Q.J.G.S.*, 1909, p. 259; fifteen specimens.
Cromer to Overstrand . .	Coast.	Grön. Pt.; Dal. F.	In B. Cl. . .	V. Madsen, *Q.J.G.S.*, 1893, p. 114. Pt. 2½ in. × ½ in. × ¾ in.; F., 2¾ in. × ¾ in. × 1 in.
Do.	—	Violet Fel. P. .	On shore . .	Do. Do. 4½ in. × 3½ in. × 2 in.
Cromer	Coast.	Zr. Sy.; Ne. Sy.; Qz. Hbl. Sch.	In B. Cl. . .	F. W. Harmer, *B.A. Rep.*, 1908, p. 245.
Cromer to Mundesley . .	—	Sär. Sy.; Dal. Qz. P.; Gr.; Spar. sst. and conglom.; Hbl. P.; Rh. P.; Lv.	On beach . .	P. F. Kendall, *B.A. Rep.*, 1904, p. 241.
East Runton	Coast.	Rh. P. . .	In Cromer Drift .	C. D. Sherborne, GEOL. MAG., 1887, p. 331.
Bacton	Coast.	Rh. P.; Lv. .	On beach. . .	F. W. Harmer and P. F. Kendall, *B.A. Rep.*, 1903, p. 236. Lv. is 3 ft. long and is striated.
Happisburgh	Coast.	Lv.	—	F. W. Harmer and P. F. Kendall, *B.A. Rep.*, 1903, p. 236.
Norwich	30–100	Qz. Hbl. Sch. .	In brick-earth .	F. W. Harmer, *B.A. Rep.*, 1908, p. 244.
Hellesdon	50	Rh. P. . .	In chalky B. Cl. .	F. W. Harmer and P. F. Kendall, *B.A. Rep.*, 1903, p. 236.
Wymondham	150	Rh. P. . .	In gravel pit .	Do. Do. p. 237.
Catton	100	Rh. P. . .	—	F. W. Harmer, *Norfolk and Norwich Nat. Soc.*, vol. ix, p. 111.

Locality.	Altitude (feet).	Rock-type.	Mode of Occurrence.	Reference and Notes.
CAMBRIDGESHIRE.				
Cambridge	—	Rh. P.; Lv.	—	A. Harker, Geol. Mag., 1894, p. 335.
Do.	—	Rh. P.; Lv.; Ld.; Nord.; Nord. P.	—	R. H. Rastall and J. Romanes, *op. cit.*, p. 252; also R. H. Rastall, Geol. Mag., 1904, p. 543.
Do. Observatory	—	Rh. P.	In gravel	J. E. Marr, *Q.J.G.S.*, 1919, p. 214; pebbles, usually small, one 12 in. × 11 in. × 7 in.
Do. Madingley Road	—	Sär. P.	On surface	J. E. A. Whealler, Geol. Mag., 1921, p. 202.
Do. Milton Road	—	Sär. P.	In gravel	Do. Do. Do.
Hardwick	200	Rh. P.; Lv.; Aeg. Gr.	On surface	R. H. Rastall and J. Romanes,[6] *Q.J.G.S.*, 1909, p. 254.
Barnwell	35	Ne. Sy.	In gravel	Do. p. 252; Scand. plutonic rocks rare.
Do.	—	Ne. Sy. with Katophorite.	—	R. H. Rastall, Geol. Mag., 1904, p. 543.[7]
Newnham	—	Soda Gr.; Aeg. Gr.	—	R. H. Rastall and J. Romanes, *op. cit.*, p. 252.
Do.	—	Nord.	—	R. H. Rastall, Geol. Mag., 1904, p. 543.
Grantchester	—	Rh P.	—	R. H. Rastall and J. Romanes, *op. cit.*, p. 260.
Impington	—	Rh. P.	—	Do. Do. Do.
Vandlebury	—	Rh. P.	—	Do. Do. Do.
Toft-Kingston district	100–150	Rh. P.; Nord.; Spar.	—	Do. Do. p. 256.
Kingston	—	Sär. P.	On surface	J. E. A. Whealler, Geol. Mag., 1921, p. 202.
Comberton, Lord's Bridge, Barton district.	50–80	Vesic. Rh. P.; Soda Gr.; Aug. Sy.; alk. Sy.; Spar.	—	R. H. Rastall and J. Romanes, *op. cit.*, p. 255. Associated with Scottish rocks, etc.
Foxton-Barrington district	60	Rh. P.; Nord.; Nord. P.; Soda Gr.; Aeg. Gr.; Spar.	—	R. H. Rastall and J. Romanes, *op. cit.*, p. 255. Associated with Cheviot rocks, etc.

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[6] The majority of boulders recorded in this paper were collected from gravel pits in operation or from arable land where there would be little likelihood of human transport. In the discussion on this paper A. E. Salter drew attention to the rounded character of the small boulders of rhomb porphyry.

[7] The quartz-porphyry identified as Dalecarlian by Professor Sjögren is in Rastall and Romanes' later paper (1909) stated to be not Scandinavian, and is later identified in Whealler's paper (1921) as a Scottish dyke-rock of Old Red Sandstone age.

Locality.	Altitude (feet).	Rock-type.	Mode of Occurrence.	Reference and Notes.
CAMBRIDGESHIRE (*continued*).				
Whittlesford — Pampisford — Hinxton—Linton.	70–150	Nord.; Rh. P.	—	R. H. Rastall and J. Romanes, *op. cit.*, p. 257. Associated with Scottish rocks, millstone grit, Bunter quartzite, etc.
Pampisford	—	Soda Gr. . .	—	R. H. Rastall, GEOL. MAG., 1904, p. 543.
Bartlow	150	Rh. P. . .	—	R. H. Rastall and J. Romanes, *op. cit.*, p. 258.
Travellers' Rest pit, Cambridge	—	Rh. P.; Lv.; Soda Gr.; Nord.; Sär. P.; Rieb. Sy.; Aeg. P.; Bark. Sy.	—	J. E. A. Whealler, GEOL. MAG., 1921, pp. 200–5.
Do.	—	Rh. P.; ? Nord. .	—	R. H. Rastall and J. Romanes, *op. cit.*, p. 254.
HUNTINGDON.				
Pidley	110	Sy. . . .	—	W. W. Watts, *Proc. Geol. Ass.*, 1893–4, p. 359.
St. Ives	30	Rh. P.; Sy.; Qz. P.	—	R. H. Rastall and J. Romanes, *Q.J.G.S.*, 1909, p. 258.
BEDFORDSHIRE.				
Clapham — Bedford — Biddenham—Kempston.	—	Rh. P.; Nord.; Spar.	—	R. H. Rastall and J. Romanes, *Q.J.G.S.*, 1909, p. 259.
Biddenham	—	Sär. P. . .	—	J. E. A. Whealler, GEOL. MAG., 1921, p. 202.
BUCKINGHAM.				
Grovebury	280	Rh. P. . .	—	A. E. Salter, discussion on Rastall-Romanes' paper, *Q.J.G.S.*, 1909, p. 263.
HERTFORDSHIRE.				
Hitchin	200	Rh. P.; alk. Sy.; Spar.	—	R. H. Rastall and J. Romanes, *Q.J.G.S.*, 1909, p. 258.
Watton	200	Metamorphosed calcareous banded sediment.	In gravel . .	G. Barrow, *Proc. Geol. Assoc.*, 1914, p. 289.

Locality.	Altitude (feet).	Rock-type.	Mode of Occurrence.	Reference and Notes.
HERTFORDSHIRE (*continued*).				
Hertford	130	Grey Gr.; Hbl. Gneiss; Basalt.	In gravel	G. Barrow, *Proc. Geol. Assoc.*, 1910, p. 170. Claimed as Scandinavian.
Do.	—	Gr.	—	H. Kidner, *T.H.N.H.S.*, vol. xiii, 1914. Large boulder claimed as Scandinavian.
Offley	500	Rh. P.	In gravel.	A. E. Salter, *T.H.N.H.S.*, vol. xii, 1904, p. 142. Associated with carboniferous limestone, jurassic fossils and debris, black chert.
Ware	130	Lv.	In gravel	R. H. Rastall and J. Romanes, *Q.J.G.S.*, 1909, p. 258; also *Proc. Geol. Assoc.*, 1909, p. 171. Collected by G. W. Lamplugh; 2 feet in diameter.
Do.	—	Rh. P.	On surface	R. L. Sherlock, *Proc. Geol. Ass.*, 1915, p. 273.
Do.	—	Ne. Sy.; Lv.	In bedded gravel	R. L. Sherlock, *Proc. Geol. Ass.*, 1915, p. 273. The Lv. has ice-smoothed faces.
SUFFOLK.				
Haverhill	200	Rh. P.	—	R. H. Rastall and J. Romanes, *Q.J.G.S.*, 1909, p. 258.
ESSEX.				
Felstead	200	Sy.	—	A. W. Howe, *B.A. Rep.*, 1888, p. 116. Also dolerites similar to Scandinavian types and many metamorphic rocks.
Barnston	200	Sy.	—	A. W. Howe, *loc. cit.*
Chesterford	130	Rh. P.; Sy.; Spar.	—	R. H. Rastall and J. Romanes, *Q.J.G.S.*, 1909, p. 257.
MIDDLESEX.				
Fortis Green, Highgate	300	Rh. P.	In B. Cl.	A. E. Salter, *Trans. Herts. Nat. Hist. Soc.*, vol. xiv, p. 140.
Finchley	250–300	Scand. rocks	In drift.	Dr. Torell, *Q.J.G.S.*, 1893, p. 115.

the boulders of the Basement Clay, as shown in Table B, are the same as those of the gravels underlying the main (Cheviot) drift of Durham except for the absence of Scandinavian boulders in the latter.

6. In conclusion, the writer is of opinion that the presence of Scandinavian boulders in the Yorkshire boulder clay is insufficient ground for the hypothesis that an ice-sheet radiating from Scandinavia has invaded the Yorkshire coast. The numerical data of the tables above show that the Scandinavian rocks constitute a very small percentage of the total far-travelled rocks of the boulder clay and that the bulk of the far-travelled rocks are Scottish in origin. Additional evidence to the same effect is provided by the existence in Durham of a boulder clay of undoubted Scandinavian character with no Scottish leanings, and by the absence of any similar clay in localities where it might be expected to occur if a general invasion of north-east England by Scandinavian ice had actually taken place.

It may be that the boulders of Norwegian rocks have been dropped on the floor of the North Sea by icebergs and subsequently incorporated in a Scottish ice-sheet, but the writer ventures to suggest for consideration in this connexion the hypothesis assumed by V. Milthers to account for the presence of Swedish boulders in East Prussia and western Russia. He says[1]: "Every single place where indicator-boulders of different origin have been found is indeed a focus of converging directions by which the boulders have come. . . . (that) the ice-stream which carried down the Åland boulders to North Germany by way of the Baltic basin received additions from the side from the southern Swedish highlands, and (that) these additions at a later period . . . constituted an essential portion of the Småland indicator-boulders contained by the ice-stream. All the discoveries of boulders throughout the whole of East Germany and West Russia bear witness to this lateral addition of Swedish materials to the Baltic stream."

A similar hypothesis applied to the British drifts appears to the writer sufficiently to account for the main features of distribution of Scandinavian boulders in Britain.

(1) It is generally accepted that the lowest boulder clays of north-eastern England and of north-eastern Scotland were laid down while there appeared to be a great obstacle occupying the North Sea.

(2) If this obstacle were an ice-sheet charged with Scandinavian boulders, it is likely that material would be interchanged between it and the British stream in contact with it—perhaps by gentle alternate waxing and waning, so that material deposited by one would be swallowed up by the other, perhaps by actual incorpora-

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[1] "Scandinavian Indicator-Boulders," *Dan. geol. Undersg.*, ii, No. 23, 1909, p. 125.

tion of foreign ice, with its load of foreign rocks, into the British stream.

(3) If the Scandinavian ice-sheet stood at a considerable distance from the British coast, and not as generally supposed, close up against the coast, the British ice could push out to sea and curl inland in a sufficiently westerly direction to account for the striae directed N.N.E.–S.S.W. which are generally attributed to a non-British ice-sheet referred to as the North Sea ice-sheet. Circumstantial evidence of the south-westerly trend of the Cheviot ice is afforded by the striae noted at Eaglescliffe by Dr. Trechmann,[1] and he quotes Mr. F. Elgee's deduction from the occurrence of Lias fossils " that the Cheviot ice moved in a south-westerly direction on to the Cleveland Hills ".[2]

(4) The outermost part of the British ice would naturally incorporate the largest proportion of foreign boulders and it is this part which would touch the British coast again farthest to the north-east and to the south-east. With regard to the northern British stream we have no data, but the evidence of the southern stream is that towards the south the proportion of Scandinavian rocks increases, while towards the north, in Durham and Northumberland, there are no non-British rocks—excluding the solitary occurrence of the unique Scandinavian boulder clay of Warren House Gill.

Such a hypothesis explains (*a*) the smallness of the proportion of Scandinavian rocks, (*b*) the constant association of Scandinavian and Scottish rocks, (*c*) the absence of any genuine Scandinavian boulder clay in those parts of England where Scandinavian boulders are most abundant, and (*d*) the increase in the proportion of Scandinavian boulders southwards.

The problem of the Scandinavian boulder clay of Warren House Gill is, in the writer's opinion, different to that of the Scandinavian boulders found in the clays of eastern England, and is one with which the present paper does not attempt to deal.

Explanation to Table C.

The altitudes, where not given in the record, were taken from Bartholomew's ½-inch to a mile map.

Where the same boulder has been reported more than once the writer has tabulated only the most accessible report, *ceteris paribus*, or the fullest.

The abbreviations used in the table are as follows :—

Act. = actinolite.
Aeg. = aegirine.
alk. = alkali.
amyg. = amygdaloidal.
Ång. = Ångermanland.
Aug. = augite.
Bark. = barkevikite.
Bred. = Bredvad.

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[1] " Scandinavian Drift of the Durham Coast," *Q.J.G.S.*, vol. lxxi, 1915, p. 72.

[2] " The Glaciation of North Cleveland," *Proc. Yorks. Geol. Soc.*, vol. xvi, pt. 3, 1908, pp. 372–82.

Conglom. = conglomerate.
Dal. = Dalecarlia.
Elf. = Elfdal.
f. = felsite
fel. = felspar.
Frdvn. = Fredriksvärn.
Gn. = gneiss.
Gr. = granite.
Grön. = Grönklitt.
Häll. = hälleflinta.
Hbl. = hornblende.
Ld. = laurdalite.
Lv. = laurvikite.
Ne. = nepheline.
Nord. = nordmarkite.
P. = porphyry.
Pt. = porphyrite.
Qz. = quartz.
Rap. = Rapakivi.
Rh. = rhomb.
Rieb. = Riebeckite.
Sär. = Särna.
Scand. = Scandinavian.
Sch. = schist.
Spar. = sparagmite.
Sst. = sandstone.
Sy. = syenite.
vesic. = vesicular.
Zr. = zircon.

In the compilation of the tables the writer has had to consult many local, rather inaccessible, journals, and wishes to express his gratitude to the librarians of the Advocates Library, Edinburgh, and of the Royal Society, Edinburgh, for permission to make use of their valuable collections.

The So-called Malone Jurassic Formation in Texas.

By F. L. Kitchin, Sc.D., Ph.D.

I. Introduction.
II. Relation to southern Marine " Provinces " of Lower Cretaceous time.
III. The Fossils of Lower Cretaceous age.
IV. Concluding Remarks.

I. INTRODUCTION.

THE known cephalopod faunas of Upper Jurassic and earliest Cretaceous age in South America were reviewed by the late Professor V. Uhlig from the standpoint of their general character and relationships.[1] In Mexico and in Texas certain lamellibranch species occur as part of a faunal development which Uhlig regarded as having an intimate connexion with the assemblages of the South Andean Jurassic-Cretaceous province. He remarked upon the regional unity shown by the faunas of Upper Jurassic age described by C. Burckhardt from the Mazapil district in Mexico, by Castillo and Aguilera from San Luis Potosi (Mexico), and by Cragin from the Malone district in Texas.[2] The fossils described from San Luis Potosi and from Cragin's so-called Malone Jurassic Formation comprise some bivalve shells, particularly *Trigoniae*, which resemble closely certain characteristic forms found in undoubted Lower Cretaceous deposits in South America, and also in the Africano-Indian province, of Krenkel's nomenclature.

It may be well to explain parenthetically at the outset that the word "province" is used here with the desire to maintain, for the purpose of this paper, some correspondence with the regional nomenclature of Uhlig, Krenkel, and others; therefore as a matter of convenience. This usage is not intended to carry such strict implications as would seem to be conveyed by the attempts at palaeogeographical reconstruction that have been made from time to time. The conceptions embodied so rigidly in the published charts of land and sea distribution during the Jurassic and Lower Cretaceous ages[1] are liable, with increasing knowledge, to become greatly modified or to break down entirely. As Dr. Spath has pointed out, they have been based too often on the comparison of faunas not strictly contemporaneous.[2] It must be admitted that they assume a most speculative character when judged by this test of strict analysis, and the gaps in our exact knowledge then become more strikingly evident. Nevertheless, these speculations undoubtedly serve a useful purpose if taken at their proper value.

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[1] V. Uhlig, " Die Fauna der Spiti-Schiefer des Himalaya, ihr geologisches Alter und ihre Weltstellung," *Denkschr. der k. Akad. Wiss., Math.-Nat. Kl.*, Bd. lxxxv, pp. 597–609, Wien, 1910.

[2] F. W. Cragin, " Paleontology of the Malone Jurassic Formation of Texas," *Bull. U.S. Geol. Surv.*, No. 266, 1905.

In the somewhat generalized discussions in which Uhlig brought this faunal region of Mexico and Texas into the closest relationship with the South Andean province, attention was chiefly focussed on the cephalopods and the significance of the specialized lamellibranchs was not fully appreciated. The fact is that the evolutionary stages exemplified by the *Trigoniae* in particular are such that, by comparison with their analogues in South America, South Africa, East Africa, and India, these forms indicate that their age is later than Upper Jurassic. Some of the fossils described by Castillo and Aguilera from San Luis Potosi are undoubtedly of Lower Cretaceous age.[3] Accepting Cragin's verdict of a Jurassic age for the Malone fauna, Uhlig put forward the suggestion that the bivalves which bear such striking resemblance to Lower Cretaceous species of the southern regions of distribution may have had long persistence and may be found in Upper Jurassic strata in one region and in Neocomian beds in another. He did not realize that the *Trigoniae* from Malone, of undoubtedly Cretaceous facies, represent evolutionary types too specialized to have had long persistence; and apparently he did not recognize the significance of the genus *Ptychomya*,[4] elsewhere known as exclusively Cretaceous, which occurs not uncommonly in Cragin's "Theta" subdivision of the Malone Formation.

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[1] Among others, V. Uhlig, "Die marinen Reiche des Jura und der Unterkreide," *Mitt. der geol. Gesellsch. in Wien*, Bd. iv, Heft 3, 1911, Taf. xiii. Mlle. S. Gillet, Thèses présentées a la Faculté des Sciences de Paris, Première Thèse: "Études sur les Lamellibranches Néocomiens," p. 292 (Carte I), Paris, 1924.

[2] See, for example, L. F. Spath, "Jurassic Cephalopoda from Madagascar," *Bull. Amer. Paleont.*, vol. xi, No. 44, 1925, pp. 28, 29. See also Dr. Spath's paper on ammonites from Somaliland (cited below), p. 160.

[3] See E. Böse, "Neue Beiträge zur Kenntniss der mexicanischen Kreide," *Centralbl. für Min.*, Jahrg. 1910, No. 19, p. 620.

[4] W. Dames, "Ueber *Ptychomya*," *Zeitschr. der deutsch. geol. Gesellsch.*, 1873, Bd. xxv, p. 379.

In another important and suggestive paper in which he dealt once more with these faunas in North and South America, Uhlig again laid stress on the unity of the Malone Jurassic fauna and that of the South Andean province, making frequent mention of the peculiar bivalves and the related assemblages farther south.[1] He discussed the subject in somewhat general terms as before, but made no further reference to the discrepancy in the indications of age afforded by the Malone cephalopods and lamellibranchs respectively. It was not suggested by him that the cephalopods of undoubted Jurassic age might have come from beds of different zonal position from that of the strata containing the lamellibranchs in question. These faunas, so diverse in age and constitution, were again indefinitely treated in combination. While Uhlig pointed out the essential unity of the bivalve fauna of the Uitenhage Beds and that of the South Andean Lower Cretaceous strata, his conception that these could be treated together with the Malone cephalopods in discussing questions of distribution is difficult to understand. The dominant types among these cephalopods are of Kimmeridge age, whereas the Uitenhage fauna is not older than Valanginian. The reference to these faunas in general terms as belonging to the Jurassic-Cretaceous junction-beds (" Kreide-Juragrenze ") does not help to lessen the confusion so repeatedly introduced by Uhlig when discussing this subject in his two papers.

Subsequently Dr. C. Burckhardt remarked that if Cragin's *Trigonia vyschetzkii* from Malone has true affinities with the Pseudoquadratae of South America and South Africa, this should lead us to assign a Lower Cretaceous age to a part of the " Malone Jurassic ".[2] At a later date the suggestion was made by Messrs. Udden, Baker, and Böse that the lowest part of the Comanchian division (Lower Cretaceous) is represented at the principal locality from which Cragin obtained Jurassic ammonites in his " Theta " subdivision, namely 1½ miles east of Malone railway station (Southern Pacific Railway). These authors stated that the Theta subdivision belongs for the most part to the Upper Jurassic, but that the presence of lowest Comanchian beds is indicated by two of the fossils figured by Cragin and considered by him to be Jurassic. They added that it was impossible to give data regarding that portion of the section which should be ascribed to the Lower Cretaceous.[3] More recently Mlle. S. Gillet has remarked on the Cretaceous character of certain of the species described by Cragin.[4]

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[1] V. Uhlig, " Die marinen Reiche des Jura and der Unterkreide," *Mitt. der geol. Gesellsch. in Wien*, Bd. iv, Heft 3, 1911, pp. 417, 426, 430, 432, 433.

[2] C. Burckhardt, " Faunes Jurassiques et Crétaciques de San Pedro del Gallo," *Boletin del Instituto Geologico de Mexico*, No. 29, 1912, p. 218, footnote.

[3] J. A. Udden, C. L. Baker, and E. Böse, " Review of the Geology of Texas," *Bull. Univ. Texas*, No. 44, 1916, p. 66 (Austin, Texas).

[4] S. Gillet, Thèses présentées a la Faculté des Sciences de Paris, Première Thèse : " Études sur les Lamellibranches Néocomiens," p. 284, Paris, 1924.

Cragin treated as a unit the whole fauna he was describing and concluded that the balance of evidence pointed clearly to a Jurassic age. He made no suggestion that the species which he thought to be of undoubted Jurassic age on the one hand, and the *Trigoniae* and the species of *Ptychomya* on the other, might have come from strata of different zonal position in the sequence, despite the fact that they were recorded by him as occurring at the same locality. Arguments, indeed, were used in favour of the Jurassic age of all these fossils.[1]

Uhlig regarded some of the ammonites described by Cragin as belonging to Burckhardt's genus *Idoceras*, of Kimmeridge age; one as probably a member of the genus *Kossmatia* Uhlig, of later Jurassic age. He believed the species of *Trigonia* or forms closely related to them to be represented in some localities in South America in beds belonging to the very base of the Cretaceous system, and thought that their occurrence in strata of Upper Jurassic age in the Malone region became thereby more easy to understand. "In view of the long persistence of bivalves it is naturally not excluded that our *Trigoniae* occur at other spots in the South Andean region in later, truly Neocomian beds. They appear, as is well known, in such Neocomian strata at Uitenhage in South Africa, while their occurrence in the Oomia Beds in Cutch is also consistent with the assumption of a somewhat later geological age."[2] The matter was thus set forth in a way that is somewhat misleading. There can be no doubt, as will presently be shown, that the comparable forms are found in South America in strata of Neocomian age.[3] In no case, however, can it be claimed that these particular species from Malone are identical with any found in more southerly parts of the South Andean province or in the Africano-Indian province. For the most part we are concerned only with the comparison of very similar morphic types or representatives of narrowly defined groups; but in some cases there is doubtless close relationship, and the comparison has important significance in the question of a general correlation.

The Jurassic age of the ammonites described by Cragin cannot be questioned. The opinion of so eminent an authority as Uhlig should scarcely need confirmation, but in view of the mixed character of the described fauna, its partial misinterpretation by Cragin, and its discrepant indications of geological age, I have asked Dr. L. F. Spath if he can give a confirmatory opinion based on an examination of Cragin's figures of the ammonites. Dr. Spath kindly informs me that he sees nothing among these illustrations to suggest a Cretaceous age. He is able, in fact, to confirm Uhlig's reading, remarking that the predominant forms of *Idoceras* are certainly Middle

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[1] Op. cit., pp. 19, 20.

[2] V. Uhlig, op. cit., 1910, p. 606.

[3] See Dr. C. Burckhardt's remarks on this point, *Bol. del Inst. Geol. de Mexico*, No. 29, 1912, p. 218, footnote.

Kimmeridgian, while "the *Haploceras*, '*Olcostephanus*' (= *Lithacoceras* of what I called the *cystettensis-fruticans* group) and '*Aspidoceras*' (*Simaspidoceras*?) may well be of the same age or Upper Kimmeridgian. The doubtful '*Perisphinctes aguilerai*' only could be a little later, possibly even a Tithonian *Kossmatia* (*pronus* zone of my Somaliland zones)."[1] Uhlig's plea for an explanation based on the long persistence of bivalves loses all weight when we consider that the *Trigoniae* from Malone are well specialized forms displaying characters never associated with long vertical range, and that the supposed persistence might involve a duration from Kimmeridge to Neocomian time.

Since no ammonites of Lower Cretaceous age were described from Malone, the evidence afforded by the bivalves must be judged entirely on its own merits; but it is of such a character that I have no hesitation in stating that beds widely separated in geological age occur at the locality broadly designated "1½ miles east of Malone railway station". An unconformable relation of these beds may be assumed to exist, and the fact that this was not detected is easier to understand when we read Dr. Stanton's account of the rocks at this locality. "The exposures are comparatively small and the dips variable, so that the stratigraphic details either as to thickness or succession can not be determined with certainty." And again: "At this point the Malone Jurassic beds are closer to fossiliferous Cretaceous beds of determined horizon than at any other place observed in the region. About three miles to the east, near the southwest base of Sierra Blanca, there are exposures of Washita beds with *Nodosaria texana* and *Gryphaea mucronata* (?) . . ."[2] It is clear also from Cragin's account of these beds[3] that their field-relations are not simple and that the record of locality is broad and generalized. No particulars were published which would indicate that the Jurassic and Cretaceous fossils were found together in the same bed or even that they occur in separate beds closely superimposed on one another at any spot. The ammonite fauna of the Jurassic horizons may be brought into comparison with that of the Jurassic strata of Mexico; the Cretaceous lamellibranchs, on the other hand, are undoubtedly closely comparable with the similar forms so widely distributed in Neocomian rocks in the South Andean province and in Africa and India. By discussing these contrasted faunas in combination in the manner he adopted, and by pleading the "long persistence of bivalves" in order to remove a difficulty that was non-existent, it has always seemed to me that Uhlig did scant justice to his great knowledge and displayed less than his usual acumen.

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[1] See Dr. Spath's account of ammonites from Somaliland, in J. W. Gregory (and others), "The Collection of Fossils and Rocks from Somaliland made by Messrs. B. N. K. Wyllie, B.Sc., F.G.S., and W. R. Smellie, D.Sc., F.R.S.Ed.," part vii, "Ammonites and Aptychi," *Mon. Geol. Dept. Hunterian Museum, Glasgow University*, i, Glasgow, 1925. Dr. Spath's "Kimmeridgian" is not equivalent in meaning to the corresponding French term, but is in close agreement with "Kimmeridge Clay" as understood by the Geological Survey. For the definition of his "Middle" and "Upper" Kimmeridgian, see L. F. Spath. "On Ammonites from New Zealand" [Appendix to Dr. C. T. Trechmann's paper], *Quart. Journ. Geol. Soc.*, vol. lxxix, 1923, p. 304 [table]. "On the Blake Collection of Ammonites from Kachh, India," *Palaeont. Indica*, N.S., vol. ix, No. 1, 1924, p. 20 [table].

[2] T. W. Stanton, "Stratigraphic Notes on Malone Mountain and the surrounding region near Sierra Blanca, Texas," in F. W. Cragin's "Paleontology of the Malone Jurassic Formation of Texas," *Bull. U.S. Geol. Surv.*, No. 266, 1905, p. 27.

[3] Op. cit., pp. 13, 14.

The several Jurassic horizons in the Malone district, of which we have indications in the described ammonites, may probably be separated by breaks in the sequence. The stratigraphical and zonal relations of these rocks within the Jurassic series there developed, and the relations of the overlying Lower Cretaceous beds to those of earlier age, remain to be ascertained by detailed observations in the field. In the meantime it must suffice to examine briefly the palaeontological evidence for the presence of Lower Cretaceous strata.

II. Relation to Southern Marine "Provinces" of Lower Cretaceous Time.

The deposits of Lower Cretaceous age in Bolivia, Chile, and the Argentine Republic, as is well known, have palaeontological characteristics in common with the Lower Cretaceous beds in South Africa and Tanganyika Territory. Related faunas of like age are also present in Madagascar, in Cutch, near Coconada (east coast of India), in Hazara (border of north-west Himalayas), and in New Caledonia. Lamellibranchs of sub-littoral facies serve, in particular, to link together the strata of Neocomian age laid down in these distantly separated regions of distribution in the two hemispheres,[1] which had doubtless a southerly connexion. In addition to a certain number of cosmopolitan types, there are groups of *Trigonia*, unknown in Europe, which have attracted much attention. Such are the species of the section Pseudo-quadratae, which illustrate a type of *Trigonia* evolution restricted to forms distributed in the two provinces mentioned and in New Caledonia. These species, such as *Trigonia herzogi* (Goldfuss), *T. holubi* Kitchin, and *T. transitoria* Steinmann, exhibit characters which show that all of them had progressed along a similar path in their descent from Clavellate ancestors, in a manner independent of, and parallel with, that followed by the familiar Quadratae of Europe. Accompanying these are the *Trigoniae* of the group of *T. ventricosa* (Krauss), which falls within Lycett's broad division Scabrae. These show an extreme type of shell evolution which is not illustrated by species known in Europe, but may be regarded as parallel with that exhibited by the European *T. aliformis* Parkinson and its allies. Examples of these southern species are *T. ventricosa* (Krauss) and *T. kraussi* Kitchin in the Africano-Indian province, and *T. subventricosa* Stanton and *T. delafossei* Bayle and Coquand in South America. The remarkable group of *Trigonia conocardiiformis* (Krauss) is likewise characteristic of the faunas in these two southern provinces (Tanganyika Territory; Cape Colony; Argentine). The peculiar group of *Trigonia vau* Sharpe of South Africa has some striking morphic counterparts in South America, the growth-stages of which, so far as known, point to actual relationship. There are other connecting links of perhaps less significant character, among them species of *Astarte* (*Eriphyla*) distinct from European forms, while the genus *Ptychomya*, represented by species different from those in Europe, is almost ubiquitous.

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[1] F. L. Kitchin, "Notes on the Invertebrate Fauna of the Uitenhage Series in Cape Colony," Geol. Mag., 1907, p. 293. "The Invertebrate Fauna and Palaeontological Relations of the Uitenhage Series," *Ann. S. Afr. Mus.*, vol. vii, part ii, 1908, pp. 49–51.

It is necessary to assume that a means of intercourse for such forms existed between these sub-littoral tracts in the eastern and western hemispheres, and it appears most probable that this was provided by the shallow waters along the south coast of an Africano-Brazilian land mass, a view put forward by Neumayr[1] and now generally accepted. Similarly, to account for the existence of a related *Trigonia* fauna in the Lower Cretaceous rocks of New Caledonia,[2] it seems most reasonable to assume an eastward shallow-water connexion by way of the southern coast of Gondwana Land, or such remnant of it as survived in Lower Cretaceous time.[3] From the characters of the related bivalve fauna in the Lower Cretaceous portion of the Oomia Group of strata in Cutch, it is evident that a direct communication existed between that area and the more southerly waters of the Africano-Indian region. Palaeontological connecting links, as is well known, are found in Tanganyika Territory. Indeed, the influence of this direct connexion is shown as far north as Hazara, on the Himalayan border.

This bivalve fauna in Cutch is so strongly contrasted with that of corresponding age in Europe as to show the unlikelihood that there was a path of intercourse suitable for the migration of such forms. Uhlig remarked that in the Jurassic series of Cutch[4] the affinities of the fauna were with the Mediterranean and Himalayan developments until late Jurassic time, but that in the higher beds yielding marine fossils, the Lower Cretaceous *Trigonia* beds, connexion with the north had apparently been cut off, since the Lower Cretaceous faunal elements of the Spiti Series are wanting in Cutch; whereas direct connexion with the Africano-Indian Lower Cretaceous province is made manifest by the character of the bivalves. The main facts may have seemed at that time suggestive of this. But it must be pointed out that the apparent absence of pre-Aptian Lower Cretaceous ammonites from Cutch is a piece of negative evidence not yet fully tested. Waagen's record of *Holcostephanus astierianus* from the Chichali Pass [1] should not be forgotten, also the traces of the bivalve fauna in Hazara; while certain species of *Astarte* since described from the Spiti Shales by K. Holdhaus appear to be closely related to forms found in the *Trigonia* beds of the Oomia group.[2] Dr. Spath has seen reason to suggest that there might perhaps have been a temporary marine connexion across Northern Africa during Tithonian and Lower Cretaceous times, that is between the "Ethiopian province" of Uhlig (Africano-Indian province of Krenkel) and the Mediterranean area, and "not only indirect communication *via* the Himalayan sea".[3]

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[1] M. Neumayr, *Erdgeschichte*, Aufl. 2, Bd. ii, 1895, p. 296.

[2] M. Piroutet, " Étude Stratigraphique sur la Nouvelle-Calédonie," pp. 127–31, Macon, 1917. S. Gillet, op. cit., p. 290. It is possible also that a related *Trigonia* fauna has some representation in New Zealand, as suggested by the occurrence of species described by Mr. Woods. See H. Woods, " The Cretaceous Faunas of the North-Eastern part of the South Island of New Zealand," *New Zealand Geol. Surv., Palaeont. Bull.*, No. 4, 1917, pp. 3–7.

[3] See the palaeogeographical reconstructions published by V. Uhlig, op. cit., 1911, Taf. xiii, and Mlle. S. Gillet, op. cit., p. 292.

[4] For a statement of the ammonite zones present in Cutch, see L. F. Spath, " On the Blake Collection of Ammonites from Kachh," *Palaeont. Indica*, N.S., vol. ix, No. 1, 1924, p. 20.

Similarly, along the area of the present American continent, a northward path of dispersal permitted the distribution of shallow-water forms from south to north, so that the facies characterized in particular by peculiar groups of *Trigonia* of southern type may be recognized in districts situated in widely different latitudes. Throughout the South Andean province the presence of these southerly faunal elements serves to maintain the contrast with the faunas of comparable age in the European area. Just as the influence of the southerly Lower Cretaceous palaeontological facies can be seen in the eastern hemisphere to have penetrated as far north as the north-west Himalayan border, so, in the western hemisphere, unmistakable evidence of a northerly penetration as far as Texas is to be recognized in the bivalve fauna described by Cragin from Malone.

III. The Fossils of Lower Cretaceous Age.

When we compare the significant species found at Malone with those in South America, South and East Africa, and Cutch to which they show resemblance, it must be admitted that the conclusion just expressed is well grounded. *Trigonia calderoni* (Castillo and Aguilera),[4] both in its shape and its peculiar sculptural plan, very strongly recalls the groups of *T. v-scripta* in India and *T. vau* in South Africa, as well as certain South American Cretaceous species with angularly disposed ribbing and strong posterior elongation.[1] In all probability the immature stages are similar to those shown by the two comparable species in South Africa and by the Patagonian *T. heterosculpta* Stanton.[2] The *Trigonia* recorded as *T. lorentii* Dana by Professor Lisson from the Isle of S. Lorenzo, Callao, Peru, may probably belong to the same group. It also has angular ribbing, but it is a less elongated shell.[3] Strongly suggestive also of a Lower Cretaceous horizon are the peculiar features shown by Cragin's *Trigonia goodelli*,[4] in which there are clearly marked analogies in the characters of successive growth-stages to *T. recurva* Kitchin of the Oomia *Trigonia* beds in Cutch. I have shown elsewhere that species of the groups of *Trigonia v-scripta* in India and *T. vau* in South Africa, so similar in adult stages, appear to be not very closely related, to judge by the features of their early growth-stages.[5] The combination of characters of shape and ornament shown by the shells of these forms, if evolved separately in different stocks, certainly produced some remarkable examples of homoeomorphy. All these species, as well as *T. glyptica* Woods from New Zealand, exemplify an evolutionary mode seen in Cretaceous *Trigonia*-stocks belonging chiefly to the southern provinces of distribution.

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[1] W. Waagen, "Jurassic Fauna of Kutch," vol. i, "The Cephalopoda," p. 245, 1875, *Palaeont. Indica*, ser. IX.

[3] K. Holdhaus, "Fauna of the Spiti Shales (Lamellibranchiata and Gastropoda)," pp. 399, 440–4, *Palaeont. Indica*, ser. XV, vol. iv, fasc. 4, 1913.

[2] L. F. Spath, in his account of ammonites from Somaliland, op. cit., 1925, p. 161.

[4] F. W. Cragin, op. cit., p. 59, pl. ix, figs. 4–6. A. del Castillo and J. G. Aguilera, "Fauna Fosil de la Sierra de Catorce, San Luis Potosi," *Bol. de la Com. Geol. de Mexico*, No. 1, 1895, p. 9, pl. v, figs. 17, 18 [as *Goniomya*]. This is not the *T. calderoni* of R. A. Philippi.

A most significant *Trigonia* from Malone is *T. vyschetzkii* Cragin, with ornamented escutcheon,[6] which must undoubtedly be regarded as a member of the Pseudo-quadratae, to which section Cragin, in fact, referred it.[7] It has much in common with *Trigonia transitoria* Steinmann, of the South American Neocomian deposits,[8] to which it appears to be closely related. It differs chiefly in the somewhat finer transverse costellae of the area; but these ornaments make their appearance at a relatively early stage in the individual development, and this fact, together with the well-established ornamentation of the escutcheon, points to a Neocomian age. All other known members of the Pseudo-quadratae are, in fact, of Lower Cretaceous age. In addition to *T. transitoria*, there are *T. neuquensis* Burckhardt (Argentine Republic), *T. steinmanni* R. A. Philippi, and perhaps also *T. erycina* and *T. lepida* R. A. Philippi (Chile), *T. herzogi* (Goldfuss) and *T. holubi* Kitchin (South Africa), *T. mamillata* Kitchin (Cutch), *T. hennigi* Lange (Tanganyika Territory), and an undescribed species in New Caledonia. The species in East Africa and South Africa are of late Valanginian age, while *T. transitoria*, which most closely approaches *T. vyschetzkii*, occurs at localities in the basin of the Rio Neuquen (Argentine) as a member of the fauna found by Bodenbinder and ascribed by Behrendsen to the Middle Neocomian.[1] This fauna was correlated by Behrendsen with that reported upon by Steinmann from Caracoles in Bolivia. The Neocomian fauna described by C. Burckhardt from the Neuquen basin, including *Trigonia transitoria*, *T. neuquensis*, another *Trigonia* showing resemblance to the peculiar *T. conocardiiformis* (Krauss) of the Uitenhage Beds in South Africa, an *Eriphyla* and a gryphaeate *Exogyra*, was thought to be probably of Lower Neocomian age.[2] Dr. Burckhardt was writing at a time when the age of the Uitenhage Beds was not known with such certainty as at present. An almost identical bivalve fauna from Loteno in the Neuquen Valley was regarded as Neocomian by O. Haupt,[3] while specimens found by M. Récopé in the same region, including *Trigonia transitoria*, *Ptychomya koeneni* Behrendsen, and *Eriphyla argentina* Burckhardt, were also ascribed to the Neocomian by the late R. Douvillé.[4] *Trigonia transitoria* was recorded from the eastern slope of the Chilian Andes by R. A. Philippi, and it was found by Hauthal at Chosmalal in Patagonia, and was ascribed to the Neocomian by F. Favre.[5]

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[1] For instance, *Trigonia arsinoe*, *T. foveata*, and others, described by R. A. Philippi, *Los Fosiles Secundarios de Chile*, pls. xxxiv, xxxv, Santiago de Chile, 1899.

[2] T. W. Stanton, *Reports of the Princeton University Expeditions to Patagonia*, 1896–99, vol. iv, Palaeontology, i, pt. i, "The Marine Cretaceous Invertebrates," p. 20, pl. iv, figs. 16–18, Princeton, 1901.

[3] C. I. Lisson, *Contribucion a la Geologia de Lima y sus Alrededores*, p. 32, pl. iii, figs. 2, 3, Lima, 1907.

[4] F. W. Cragin, op. cit., p. 58, pl. x, figs. 1, 2.

[5] *Ann. South African Mus.*, vol. vii, part ii, 1908, pp. 112, 119.

[6] F. W. Cragin, op. cit., p. 56, pl. viii, figs. 1, 2; ix, figs. 1–3.

[7] G. Steinmann, "Die Gruppe der *Trigoniae* Pseudo-quadratae," *Neues Jahrb. für Min.*, 1882, Bd. i, p. 219. F. L. Kitchin, "Jurassic Fauna of Cutch," vol. iii, part ii, Genus *Trigonia*, 1903, p. 98, *Palaeont. Indica*, ser. IX. "Invertebrate Fauna and Palaeontological Relations of the Uitenhage Series," *Ann. South African Mus.*, vol. vii, part ii, 1908, pp. 101–10. S. Gillet, *Études sur les Lamellibranches Néocomiens*, p. 96, Paris, 1924.

[8] G. Steinmann, op. cit., p. 221, pl. vii, figs. 3, 4; pl. viii, figs. 1–3. "Zur Kenntniss der Jura- und Kreideformation von Caracoles," *Neues Jahrb. für Min.*, Beil.-Bd. i, Heft 2, 1881, p. 260, pl. xiii, fig. 3. C. Burckhardt, "Coupe Géologique de la Cordillère entre Las Lajas et Curacautin" [descriptions of Neocomian fossils by C. Mayer-Eymar, pp. 17–23], *Annales del Museo de La Plata, Seccion Geol. y Mineral.*, iii, 1900, p. 21, pl xxv, figs. 1–3. "Beiträge zur Kenntniss der Jura- und Kreideformation der Cordillere," *Palaeonto-*

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graphica, Band 1, 1903, p. 73, pl. xiv, figs. 1, 2. R. A. Philippi, *Los Fosiles Secundarios de Chile*, p. 63, pl. xxix, figs. 5–7, Santiago de Chile, 1899. A *Trigonia* closely resembling *T. transitoria*, recorded and figured under this name by Dr. E. Lange, occurs in the Neocomian of Tanganyika Territory.

[1] O. Behrendsen, "Zur Geologie des Ostabhanges der argentinischen Cordillere," *Zeitschr. der deutsch. geol. Gesellsch.*, Bd. xliv, 1892, pp. 15–27, 37, 38.

[2] C. Burckhardt, op. cit., *Palaeontographica*, Band 1, 1903, pp. 72–6, 95, 111, 112.

[3] O. Haupt, "Beiträge zur Fauna des oberen Malm und der unteren Kreide in der argentinischen Cordillere," *Neues Jahrb. für Min.*, Beil.-Bd. xxiii, 1907, pp. 207–22, 225.

[4] R. Douvillé, "Céphalopodes Argentins," *Mém. Soc. Geol. France, Paléont.*, Mém. 43, 1910, p. 20.

[5] F. Favre, "Die Ammoniten der unteren Kreide Patagoniens," *Neues Jahrb. für Min.*, Beil.-Bd. xxv, 1908, p. 610.

Other species of *Trigonia* from Malone show characters which speak no less insistently for an age later than Upper Jurassic. *T. proscabra* Cragin, of the section Scabrae, judging by the occurrence of all known similar forms, would alone testify unmistakably to the Cretaceous age of the bed which yielded it. Comparable members of the Scabrae (*T. delafossei* Bayle and Coquand [1] and *T. nepos* Paulcke) are among the *Trigoniae* included in the Neocomian fauna described by W. Paulcke from localities in Chile.[2] In addition to these and the Pseudo-quadrate *Trigonia transitoria*, the fauna comprises *T. progonos* Paulcke, a remarkable member of the Scabrae showing a division of the costae into two separate series, comparable in this respect with the more delicately ornamented *T. pulchra* Kitchin, from the Oomia *Trigonia* beds in Cutch.

Not one of the species of *Trigonia* from Malone can be brought into relationship with the Jurassic Undulatae, as thought by Cragin, nor can the representatives of the section Costatae described by him be utilized as evidence for a Jurassic age, since extended knowledge has in recent years refuted the view once held that this section of *Trigonia* is confined to the Jurassic rocks.[3] *Trigonia munita* Cragin illustrates a type of degeneracy which is in itself suggestive, while the characters of sculpture in *T. rudicostata* Cragin and *T. conferticostata* Cragin, with delicate ribbing, strikingly recall *T. tenuis* Kitchin, a finely ribbed member of the Costatae from the *Trigonia* beds of the Oomia Series in Cutch. Another of the delicately ribbed Costatae of Lower Cretaceous aspect is the shell recorded by Professor Lisson as *Trigonia* cf. *angustecostata* Behr., from the Isle of S. Lorenzo, Peru,[4] comparable again with the Indian *T. tenuis* and also with *T. parva* Kitchin, associated with species of the Scabrae in Cutch. If the suggestion of Dr. E. Lange is correct,[5] that *Trigonia burckhardti* Jaworski, from Piedra pintada, Neuquen (Argentine),[6] may be one of the degenerate *Trigoniae* of the section Costatae, closely analogous to *T. smeei* J. de C. Sowerby of Tanganyika Territory and Cutch, then we have one more point of resemblance between these faunas of the South Andean and Africano-Indian regions.

Evidence for the presence of Cretaceous beds at Malone no less strong than that provided by the *Trigoniae* is to be found in the occurrence of *Ptychomya stantoni* Cragin.[7] This is a typical representative of a specialized genus of shells, elsewhere known to occur only in rocks of Cretaceous age. The genus is represented in the Neocomian beds of South America, for instance, by *P. koeneni* Behrendsen and *P. crispa* (R. A. Philippi), as also in South Africa and Tanganyika Territory. Some suggestive evidence, though less decisive than that provided by *Ptychomya* and *Trigonia*, is obtainable also from an examination of Cragin's illustrations of other lamellibranchs. Many of these have more generalized types of shell and some may well have been obtained from Jurassic levels in Cragin's Theta series. But the characters of *Astarte* (*Eriphyla*) *malonensis* Cragin, which has a pronounced pallial sinus and degenerated surface ornaments, recall several species of *Eriphyla* present in the Lower Cretaceous rocks in districts of the South Andean province and the Africano-Indian region (Argentine Republic, Cape Colony, Tanganyika Territory, and Cutch). Some of the oysters also from Malone have the characters of Lower Cretaceous species. Such are the forms ascribed by Cragin to *Gryphaea mexicana* Felix, with posterior flattening of the left valve, and *Exogyra potosina* Castillo and Aguilera, a larger shell showing a postero-superior flattening or concavity of the surface of the left valve, bounded by a subcarinate fold of the valve extending back from the umbonal region towards the posterior margin. This general type of exogyrate shell, showing a gryphaeate habit, is common among the Lower Cretaceous oysters in almost all regions of distribution and is not met with in Jurassic rocks. It must further be noticed that some of Cragin's figures of shells (including more than one species) referred by him to *Pleuromya inconstans* Castillo and Aguilera, show much resemblance to forms of *Panopea* occurring in the Lower Cretaceous rocks of Europe.

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[1] E. Bayle and H. Coquand, "Mémoire sur les Fossiles Secondaires recueillis dans le Chili par M. Ignace Domeyko," *Mém. Soc. Géol. France*, sér. II, vol. iv, 1851, p. 37, pl. viii, fig. 27.

[2] W. Paulcke, "Ueber die Kreideformation in Südamerika und ihre Beziehungen zu anderen Gebieten," *Neues Jahrb. für Min.*, Beil.-Bd. xvii, Heft. 2, 1903; list on p. 302.

[3] See F. L. Kitchin, *Ann. South African Mus.*, vol. vii, 1908, p. 126.

[4] C. I. Lisson, *Contribucion a la Geologia de Lima y sus Alrededores*, p. 35, pl. iv, fig. 3, Lima, 1907.

[5] E. Lange, "*Trigonia Smeei* und ihre horizontale Verbreitung," *Centralblatt für Min.*, etc., 1917, p. 492.

[6] E. Jaworski, "Beiträge zur Kenntniss des Jura in Süd-Amerika," Theil ii, *Neues Jahrb. für Min.*, Beil.-Bd. xl, Heft. 2, 1915, p. 380, pl. v, fig. 3.

[7] F. W. Cragin, op. cit., p. 69, pl. xii, figs. 4–6.

The combined evidence of the species above discussed thus affords sufficient proof of the age and relationships of this Lower Cretaceous fauna in Texas. In the absence of ammonites precise zonal correlations are not yet possible. There is no proof that the specimens all came from a single Lower Cretaceous horizon; but the general aspect of the assemblage suggests that it comprises nothing of earlier age than Valanginian. The presence of ammonites in the South African Uitenhage Beds, which yield species of "*Holcostephanus*", now separated under the generic name *Rogersites* by Dr. Spath,[1] shows the late Valanginian age of that series. The Lower Cretaceous *Trigonia* fauna found in different districts of the South Andean province can for the most part be regarded as not older than Valanginian.

The exact age of the related bivalve fauna in the "Belgrano Beds" of Patagonia, described by Dr. Stanton,[2] has not been determined with certainty, but it was regarded by Stanton as of Lower Cretaceous age. As a result of the study of specimens collected at the Cerro Belgrano and Meseta Belgrano by Hauthal, F. Favre thought that the fauna with *Hatchericeras* in the Belgrano Beds (the Tarde Stage of Ameghino) should be ascribed to an age later than Hauterivian.[1] By Uhlig and others it was placed below the Valanginian; but until more exact knowledge of the field-relations can be obtained we may still have reason to doubt whether the bivalve fauna is older than Valanginian. Uhlig linked it up with the *Trigonia* fauna found farther north in Argentine and Chile and in the Uitenhage Beds of South Africa. " One can have no doubt not only that this fauna is distributed through the whole South Andean region from Patagonia to Malone, but that it is essentially identical with the Uitenhage *Trigonia* fauna of South Africa." [2] We must remember, however, that he was content to regard the fauna as Neocomian in South Africa, Infravalanginian in Patagonia, and Jurassic (perhaps so old as Kimmeridge) in Texas. As already mentioned, Favre recorded the occurrence of *Trigonia transitoria* Steinmann at the locality Chosmalal in Patagonia, and ascribed a Neocomian age to the bed containing it; [3] but the relations to the *Trigonia* fauna of the Belgrano Beds described by Stanton from localities east of Lake Pueyrrydon are unknown.

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[1] L. F. Spath, "On the Ammonites of the Speeton Clay and the subdivisions of the Neocomian," GEOL. MAG., 1924, p. 86.

[2] T. W. Stanton, *Reports of the Princeton University Expeditions to Patagonia*, 1896–9, vol. iv, Palaeontology, i, part i, "The Marine Cretaceous Invertebrates," Princeton, 1901.

The *Trigonia* fauna has not yet been reported as occurring in the "*Astieria*" beds of Mexico,[4] unless it be that *Trigonia calderoni* and *Exogyra potosina*, described by Aguilera from the Sierra de Catorce, occur in the same beds as his *Olcostephanus potosinus*, from the same district.[5] Imperfect collecting or the neglect to report the occurrence of bivalves, the local absence or rarity either of cephalopods or of lamellibranchs, or the distribution of the shells of these separate classes locally in different beds, are all possible explanations; or it may be that the Malone Cretaceous bivalves occur in earlier Valanginian strata, not characterized by the presence of "*Astieria*".

IV. CONCLUDING REMARKS.

It may be concluded that the strata comprised in Cragin's so-called Malone Jurassic Formation belong to several, in part widely separated horizons. There is no evidence of the presence of Jurassic beds of earlier age than Kimmeridge. Two or more Jurassic horizons are represented, and there may probably be breaks in the series. Overlying these strata, and with a relation to the lower series not yet made known, are Lower Cretaceous beds which may be regarded as of Valanginian age. These contain a bivalve fauna related to that of the southern *Trigonia* seas, in which were laid down the Lower Cretaceous deposits of sub-littoral character found in the Andean region and in Patagonia ; in Cape Colony, Madagascar, Tanganyika Territory, and Cutch ; and in the now isolated region of New Caledonia.

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[1] F. Favre, " Die Ammoniten der unteren Kreide Patagoniens," *Neues Jahrb. für Min.*, Beil.-Bd. xxv, 1908, p. 644. See also O. Wilckens, " Die Meeresablagerungen der Kreide- und Tertiär-formation in Patagonia," *Neues Jahrb. für Min.*, Beil.-Bd. xxi, 1906, pp. 122, 128–30.

[2] V. Uhlig, *Mitt. der geol. Gesellsch. in Wien*, Bd. iv, Heft. 3, 1911, p. 426.

[3] F. Favre, op. cit., p. 610.

[4] C. Burckhardt, " La Faune Jurassique de Mazapil, avec un Appendice sur les Fossiles du Cretacique Inférieur," *Bol. del Inst. Geol. de Mexico*, No. 23, 1906, p. 183. " Faunes Jurassiques et Cretaciques de San Pedro del Gallo," ibid., No. 29, 1912, p. 196. E. Böse, "Algunas Faunas Cretacicas de Zacatecas, Durango y Guerrero," ibid., No. 42, 1923.

[5] A. del Castillo and J. G. Aguilera, " Fauna Fosil de la Sierre de Catorce, San Luis Potosi," *Bol. de la Comision Geol. de Mexico*, No. 1, 1895, pp. 3, 9, 36.

This southern bivalve fauna, so widely distributed, occurs in strata deposited certainly within the period from the beginning of Cretaceous time to late Valanginian ; it is probably entirely Valanginian. These beds can only be studied in isolated remnants separated by great distances. Such vestiges must give an imperfect picture of the trends of the former sea-margins, and the attempts that have been made to draw palaeogeographical reconstructions probably err in regard to the great areas allotted to the hypothetical continental masses.[1] The fauna shows a facies of its own that is remarkable, and it is of interest to observe that certain specialized types of bivalves have such widespread group-representation throughout these southern seas, but did not penetrate to the European area.

The groups of *Trigonia*, in particular, are so distinct from those of Europe that it appears that they had their origin in the southern waters, like the representatives of the specialized genus *Seebachia*, which, however, is confined to the Africano-Indian region. Restriction to the southern seas and their direct northern extensions was probably determined chiefly by the distribution of land and water ; the specialized lamellibranch-stocks (often showing degenerate features of the shell) which so largely give character to the fauna, were of a kind unlikely to have had the long persistence which might favour dispersal to the European area by means of the indirect communications then open. It is uncertain whether there was a direct connexion with the Mediterranean region at the north of the Africano-Indian sea ; the character of the bivalve-fauna in Cutch seems to speak against the existence of communications so direct as to permit free intercourse between the contrasted lamellibranch faunas of the European and Indian seas. That there was a connexion across the present North Atlantic area permitting intercourse between the European and South Andean waters, at least for cephalopods, is supported by the evidence from Mexico. It is improbable that the distribution of the widespread southern bivalve fauna was determined chiefly by climatic conditions, in view of its extensive dispersal in greatly differing latitudes in both hemispheres.

[1] See S. Gillet, op. cit., p. 292 (Carte i). V. Uhlig, op. cit., 1911, Taf. xiii.

The faunas of the southern Lower Cretaceous *Trigonia* beds of different districts, apart from that found in Texas, have been misinterpreted again and again. The Neocomian Uitenhage Beds of South Africa were for long considered to be of Jurassic age, and were thought by R. Tate to be a condensed representative of many Jurassic zones of Europe, though not including any of the highest Jurassic horizons. The *Trigonia* beds of the Oomia Series in Cutch were thought by Waagen and Feistmantel to be of Jurassic age. The species of Neocomian age in Tanganyika Territory were interpreted correctly by Müller and by Krenkel[1]; but since the Tendaguru Expedition of 1909–12 needless confusion and error have been introduced by the treatment of some of the fossils by E. Hennig, J. Zwierzycki, and E. Lange.[2]

An interesting group of degenerate Costate *Trigoniae*, including *T. smeei* J. de C. Sowerby, previously only known from the Oomia *Trigonia* beds in Cutch, has been found to be well represented in the " Tendaguru Beds ". Lange conceives the species *T. smeei* so comprehensively as to include in it *T. beyschlagi* G. Müller as well as *T. crassa* Kitchin from Cutch, both of which are certainly Neocomian forms, as shown by their associates. He records the species as occurring in the Valanginian *Trigonia schwarzi* bed of the Tendaguru sequence, but states that it is more characteristic of the underlying " *Trigonia smeei* bed ", and that it is there associated with Jurassic ammonites. As pointed out by Dr. Spath, all these ammonites are Middle Kimmeridge forms, and no Jurassic ammonites of later age than Kimmeridge are known from East Africa.

Other Valanginian species are ascribed to this " *Trigonia smeei* bed " (20 metres in thickness), including *Trigonia ventricosa* (Krauss), *Seebachia bronni* (Krauss), *Astarte* (*Eriphyla*) *herzogi* (Goldfuss), and *Gervillia dentata* Krauss, which in association form part of the special fauna of the Uitenhage Series in South Africa. All the fossils from the " *T. smeei* bed ", including these Neocomian forms, are referred to the Kimmeridge by Lange. He arrives at the astonishing conclusion that this entire assemblage of bivalves was capable of persisting unaltered through the long ages from Kimmeridge to

[1] G. Müller, " Versteinerungen des Jura und der Kreide," in *Deutsch-Ost Africa*, Band vii, Theil 2, pp. 514–71, Berlin, 1900. E. Dacqué and E. Krenkel, " Jura und Kreide in Ostafrika," *Neues Jahrb. für Min.*, Beil.-Bd. xxviii, 1909, pp. 190–7. E. Krenkel, " Die untere Kreide von Deutsch-Ostafrika," *Beiträge zur Pal. und Geol. Oesterr.-Ungarns und des Orients*, Bd. xxiii, pp. 201–50, 1910. " Zur unteren Kreide von Deutsch-Ostafrika," *Centralbl. für Min.*, etc., Jahrg. 1911, No. 9, pp. 285–8.

[2] In " Wissenschaftliche Ergebnisse der Tendaguru-Expedition, 1909–12." E. Hennig, " Beiträge zur Geologie und Stratigraphie Deutsch-Ostafrikas," *Archiv. für Biontologie* (herausgegeben von der Gesellsch. Naturforschender Freunde zu Berlin), Band iii, Heft 3, 1914. J. Zwierzycki, " Die Cephalopodenfauna der Tendaguru-Schichten in Deutsch-Ostafrika," ibid., Band iii, Heft 4, 1914, p. 7. E. Lange, " Die Brachiopoden, Lamellibranchiaten und Anneliden der *Trigonia Schwarzi*-Schicht, nebst vergleichender Übersicht der Trigonien der gesamten Tendaguruschichten," ibid., Heft 4, 1914, p. 291.

Valanginian time, a fantastic conception. It is evident that something has gone seriously amiss either in the collecting or recording. It is most probable that the base of the local marine Neocomian strata rests immediately upon a bed of Middle Kimmeridge age, at some level in the series situated just beneath the "Upper Saurian Horizon", and that the unconformity was not detected. It seems significant that some of the Valanginian fossils are stated to occur there in a coarse conglomerate. Lange endeavours with much elaborate argument to sustain a view (accepted also by his collaborators) that must certainly have been based upon unsound data; and the result does little credit to the perspicacity of these German authors. Professor Krenkel has unfortunately perpetuated the confusion in his valuable book on the geology of Africa.[1]

Although mistakes of this kind may be so palpable that their detection is easy, as in the case just mentioned, progress in stratigraphical and palaeontological work is too often seriously retarded by them. One of the chief aims of the present paper has been to rectify some of these errors.

Recent Volcanic Eruptions in the Central Alpine, so-called "Hercynian", Zone.

By C. G. S. SANDBERG, D.Sc.

(PLATE XXVIII.)

IN a mighty curve, convex to the west and north, the Central Alpine Zone trends from the Mediterranean to the eastern confines of Switzerland in the north-east, marked by a series of granite massives, the principle of which are: Mercantour, Pelvoux, Belledonne, Mont Blanc, Aar, and St. Gotthard.

The eruptive rocks of these Central Massives are currently considered to be of Hercynian age, i.e. they are supposed to have been consolidated in pre-Triassic times.

E. Weinschenk, until his death, and independently of him the writer since 1905 opposed this view, contending that these granites, like the other Alpine eruptives, are of Tertiary, of Alpine orogenetic age. The only granites and associated eruptive rocks which since about 1913 are admitted to be of Tertiary age, in the Western Alps, are those of the Bergeller or Bregaglia and Biella-Travestella regions. Younger eruptives are not recognized, except perhaps for some enigmatic tuffs and lavas of problematic origin, known as the Taveyannaz sandstones, which in the outer zone of the Central Granite curve have been recognized, trending, at intervals, from the western foot of the Diablerets to Vättis (north-west of Chur), i.e. over an airline distance of some 170 km. (1, vol. ii, p. 346).[2]

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[1] E. Krenkel, *Geologie Afrikas*, Theil i, pp. 308–15, Berlin, 1925.

[2] Numbers in parentheses refer to bibliography at end.

In 1921 E. Hugi described some very remarkable examples of magmametamorphism (contactmetamorphism) in and round the Mont Blanc-Aar-St. Gotthard massives. From a far advanced magmatization (crystalline schists) of the sedimentary strata in the immediate vicinity of the granitic intrusions, Hugi succeeded in tracing the gradually diminishing magmatic action on younger strata of the St. Gotthard envelope right into very probably Jurassic sediments (2, p. 481; 3, p. 107).

Having established this, one would expect Hugi to conclude that the granitic intrusion took place in Tertiary times. Strange as it may seem, however, he does not, and even adheres to the current conception, that the intrusion, the " mise en place " of the Central Granites took place in Hercynian times.

Now, either Hugi's claim to have traced an uninterrupted chain of evidence of metamorphism the extremes of which are the contact-metamorphic crystalline schists on the one side, and the pneumatolytic-hydrothermal phenomena in the younger strata on the other is questionable, or it is not. The first alternative even his worst antagonists would reject. There remains consequently only the second one, namely that his observations are correct (1, p. 921). In that case, the only admissible conclusion is that the " mise en place " of the so-called Hercynian granites occurred in post-Jurassic time (4) (5).

However, the grand structure of Alpine tectonic geology, developed into such a wonderful complex during the last two decades, is based on and inseparably tied to the notion of some tangentially directed forces having originated the terrestrial mountain systems and is dominated by the presumption of the Paleozoic age of the Central Granites.

Thus, in spite of the serious consequences to geological science increasing with process of time, the assumed Hercynian age of the Western Alpine granites, with the exception of the Bergeller-Biella-Travestella eruptives, is being maintained, although the contention is in flagrant contradiction to facts admitted by its very formulators. In fact, as early as 1905 (4) I established, with regard to the sedimentary complex of the Pierre-à-Voir massive, a gradual and imperceptible transition from the magmametamorphosed complex (gneisses and associated rocks), through the Casanna facies of the Permo-Carboniferous to the Triassic quartzites and beyond. This fact, afterwards verified by E. Argand (6), which he proved to be applicable to the entire Pennine region of the Alps, is now generally admitted, *lithologically*, *stratigraphically*, *and tectonically*.

Now, whilst the metamorphism of the Permo-Carboniferous and older strata all though the Alps is admittedly of magmatic origin, the fiction is yet tenaciously upheld that the basal Triassic quartzites, although passing imperceptibly into the underlying Permo-Carboniferous deposits, derive their metamorphism from some different source (1).

Without further comment it is clear already that the current view, that in the Alps, outside the Bergeller-Biella-Travestella-regions no magmametamorphism of strata younger than Permian

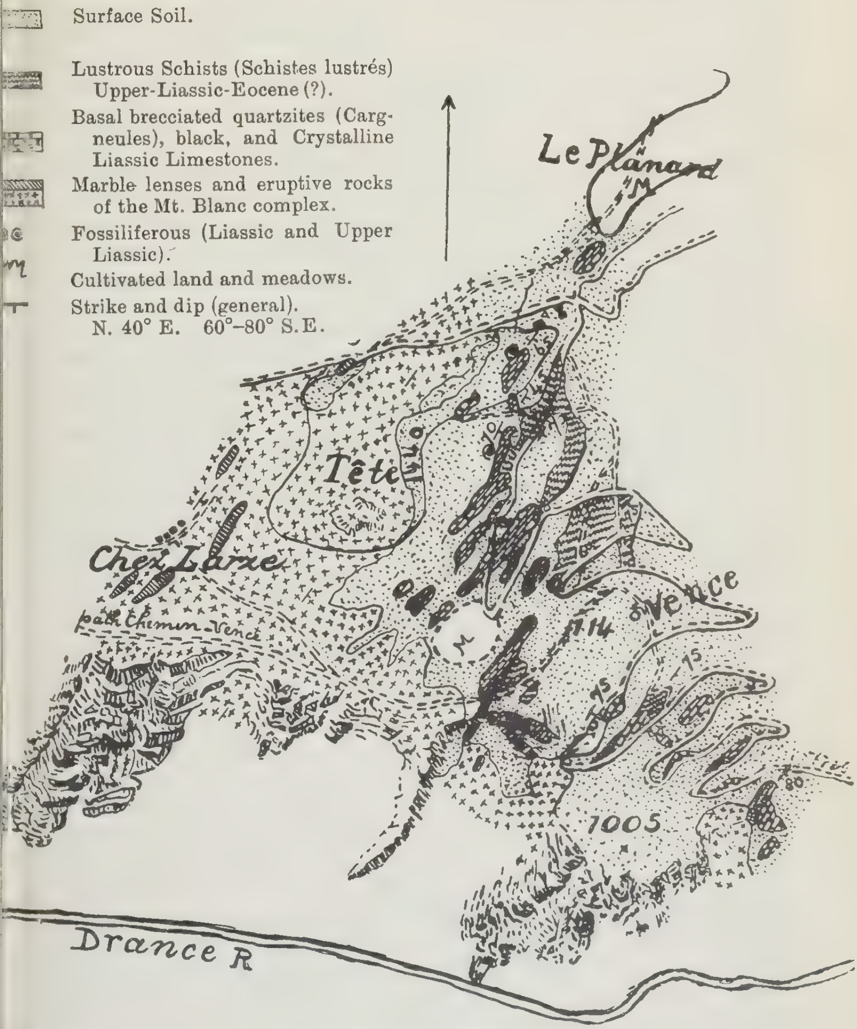
Surface Soil.
Lustrous Schists (Schistes lustrés) Upper-Liassic-Eocene (?).
Basal brecciated quartzites (Cargneules), black, and Crystalline Liassic Limestones.
Marble lenses and eruptive rocks of the Mt. Blanc complex.
Fossiliferous (Liassic and Upper Liassic).
Cultivated land and meadows.
Strike and dip (general). N. 40° E. 60°–80° S.E.
Le Planard
Tête
Chez Larze
path Chemin Vence
Vence
1114
75
15
80
1005
Drance R

FIG. 1.—Map of the contact near Vence between the Mt. Blanc eruptive complex and its sedimentary cover E. of Martigny (Valais).

occurred, is inadmissible and fictitious, which conclusion is in perfect harmony with the result of Hugi's work and of my own recent studies in the contact zone of Vence, to east of Martigny.

These latter led me to test the value of yet another allegation which is constantly repeated in support of the pretended antiquity of the Central Granite. It is alleged that notably in the zone of contact near Vence, between the eruptive complex of the Mont Chemin and its sedimentary cover, the latter (*a*) unconformably overlies the former; and (*b*) is not magmametamorphosed by the eruptives of the Central Massives. As to (*a*) I frankly admit having laboured under that impression myself in 1905 (4) for the current adoption of which I may have been co-responsible. This impression is forced upon one by a division plane, inclining about 45° S.E. which is very persistent and well developed in the Liassic crystalline limestones covering there the basal Triassic quartzites, and underlying the exceedingly laminated lustrous clay schists, all isoclinally arranged. The eruptive complex of the Mont Chemin (north-east extension of the Mont Blanc Massive) which immediately underlies the said sedimentary complex, strikes in the very same direction as the latter and dips at angles varying from 60° to 80° S.E. The real stratification of the sedimentary strata not being well marked in the natural outcrops, the divisional planes are naturally mistaken for their dip and hence lead to the conclusion of a stratigraphical unconformability between the two complexes. During my recent visit to these regions in March–April of this year, I found that a motor-car road had been constructed (since 1905) from Sembrancher to the Col des Planches, via Vence, disclosing some fine and remarkable sections of this very contact zone. Moreover I discovered to the south of the path leading from Chemin-Dessus to Vence and well inside the eruptive area, a clear outcrop of the contact between the two complexes. I could thus establish that at various places (see Fig. 1) the real dip of the sedimentary strata is perfectly conformable with that of the eruptive complex and that the inclination which was taken as that of stratification is in reality one of divisional planes. The above-mentioned unconformity argument will therefore have to be definitely abandoned.

(*b*) When approaching from the east the actual zone of contact (see Fig. 1) we perceive that the highly crystalline fossiliferous Liassic limestones gradually lose their fossiliferous contents and become lighter in colour until quite white. At the same time they become finer grained, finally changing into marble and a compact hornstone, very much cleaved and broken.

Now in 1905 I established that the fossiliferous members of this sequence, those farthest away from the actual contact, contain felspar (albite), quartz, epidote, mica, tourmaline and magnetite (4, pp. 107–108). It is clear therefore that these Liassic limestones were subjected to a post-Liassic magmametamorphism by the magma, the consolidated products of which now constitute the eruptive complex of the Mont Chemin (Mont Blanc). Correspondingly we must expect the Triassic quartzites, although much more refractory, to show signs of having been magmametamorphosed.

Actual contacts with the underlying schists are scarce; generally these quartzites are found in interrupted zones consisting of brecciated lumps of a rock, composed of fragments of quartzite, crystalline limestone and metamorphic schists (generally already fairly decomposed) kneaded together to a very tough and resistant body, known as "cargneules". Its elements vary from a size of several cubic centimetres to that of one millimetre and less. I found it in actual contact with the underlying schists at a point some 30 metres below the path leading from Chemin-Dessus to Vence (see map). Very compact, intensively fractured and brittle, the rock, under the pocket lens, shows a porphyroid structure, quartz, felspar, and shale fragments being imbedded in a compact groundmass. The fragments of the harder elements, quartz and felspar, are angular and sharp, whilst those of the softer schists are more or less blunt. Specimens taken here were kindly examined microscopically by Professor J. A. Grutterink, Professor of Petrology at the Technical University of Delft (Holland), who wrote as follows (translated):

"*Quartzite rich in felspar, and shales.* The rock consists of hardly rounded, angular grains of quartz, felspar and shale and some quartz porphyry, cemented by newly formed quartz. The quartz grains clearly show pressure phenomena, such as undulatory extinction, mosaic polarization, fractures. The felspar is partly orthoclase, partly acid plagioclase; it also shows signs of having been subjected to pressure, the borders being crushed; micrographic intergrowth with quartz was noticed.

"Grains of quartz porphyry are scarce; they consist of rectangular prisms of orthoclase and small lamellae of mica, fluidally arranged round the remains of primary quartz crystals.

"The shales which furnished some of the material of this rock are of various nature: fine grained and coarser silicicous shales, originally impregnated by iron-pyrites crystals now transformed into limonite, which latter is also segregated in the small fractures of the shale, thus colouring its fragments dark; fine grained shales rich in small flakes of mica are also present. Some larger flakes of mica (muscovite) and small zircon crystals are also noticed.

"The newly formed quartz partly appears as rods radially arranged round the older crystals, partly as sphaerolites. Generally it is found between the older crystals forming an aggregate of interlocked irregular grains of various size exactly like a quartzite. In between lies a fine powder, the product of the crushing and grinding of the other fragments.

"The rock looks like a product of sedimentation, an impure sandstone; yet such a rock can be the product of crush and the interkneading of subsequent fragments" (cf. also (4) pp. 102–4).

Now field relations conclusively prove that the peculiar habit of the rock is of tectonic and metamorphic origin, a product of crush and interkneading of contiguous strata subsequently magmametamorphosed (felspathization). In fact the very quartzite a little further to the north-east and stratigraphically a little higher up, where it is in direct contact with the overlying crystalline limestones, is brecciated as here, yet constitutionally different. There the fragments instead of being quartz, felspar, and shale, are quartz, felspar, and limestone. At both places the constituent fragments are angular, showing that they are not the *denudation-products* of pre-existent strata but derived from those in situ by crush and interkneading of the contiguous parts of the strata concerned. The felspar, moreover, so abundantly present and of considerable size, sharp-edged and angular and fresh at that, cannot have been derived from the very fine grained, micaceous, pyritic and much decomposed shales below the quartzite. We have consequently to admit that their presence is due to contactmetamorphism, which again would prove that the magma, the consolidation products of which constitute the Central Granites and associated rocks, was still in an unconsolidated condition in post-Triassic and post-Liassic times. Although the facts above described would seem to prove beyond any doubt the post-Liassic age of the Central Granites, we will add some more evidence to that effect, so that this question, the bearing of which reaches far beyond its connexion with Alpine geology even, may be settled once for all. For that purpose we will go over to the other side of the Rhone valley, to the Diablerets group.

Alb. Heim (1, pt. i, vol. ii, pp. 460–1) mentions that serious landslips occurred in the Diablerets in the years 1714 and 1749. Translating the tectonic part of the description of the occurrence in substance, it runs: "Among the historically established landslips (Bergsturz) of the region the landslip (Felssturz) of the Diablerets is the largest. It caused a scar, some 800 metres east of the highest summit, in the mountain flank of some 3,000 metres in height and formed of flat lying schists gently dipping towards the south-east. The occurrence was therefore a fracture across the schists, its fracture surface and sliding plane not one of bedding or stratification; a real 'Felssturz' . . . *After several days of continual subterraneous rumbling* the first tremendous downfall occurred on September (?) 24, 1714, between 2 and 3 p.m. . . . killing 15–18 people, cattle . . . etc. A second, evidently much bigger, downfall occurred on June 23 (dates recorded vary slightly), 1749. *The inhabitants knowing the signs* fled in time . . ." (The italics are mine).

A "real Felssturz"; the consequences are there to prove historical evidence recorded in the annals and preserved in the archives. Yet such phenomena are usually *not* preceeded by *subterraneous rumblings continuous, moreover, during several days*; in 1714 as in 1749. Such forebodings are to my knowledge, inherent only in volcanic eruptions. As Heim does not give a solution of this enigma we have to search elsewhere.

Now A. Ceresole (7, p. 129 ff.) quotes from official documents in the archives of Bex, to which the devastated region belongs, the following record of the occurrence above mentioned :—

"La montagne, quelques jours de suite auparavant, avait fait grand bruit, quoique d'une manière sourde ; et 24 heures avant sa chute, on entendait de temps en temps des coups comme d'un canon. Après cela, on vit sortir du sommet de la montagne, qui était fort haute, une fumée épaisse, qui fut suivie d'une grande flamme ; en suite de quoi . . . elle creva et se sépara par morceaux . . ."

Soberly as the record is worded, it yet cannot leave any doubt of the nature of the occurrence being that of a volcanic eruption, which, as an accessory phenomenon, caused the landslips (Felssturz) in 1714 and again in 1749. Now the enigma of *subterraneous rumbling preceding for several days continuously the landslip occurrence* is solved and rationally explained. And it seems well to mention here that similar documentary evidence exists, according to the same author (7, p. 309) in the archives of Aigle about an eruption which took place in 1584 of the Cirque de Luan. We shall have occasion to refer to these records further on. Such volcanic manifestations being so closely and inseparably connected with the unconsolidated state of the magma in time and place, we may claim to have conclusively proved the validity of our contention adhered to and defended ever since 1905, namely : *The granites of the so-called Hercynian or Central Massives, like the other Alpine granites, are of Tertiary age and synchronous with that of the Alpine orogenesis* (which their eruption originated (5)). In fact, it need hardly be insisted upon that the granites of the Western Alpine Central zone belong to one and the same province and period of eruption ; nor that they form the substratum of the Diablerets volcano (8), the Blümlisalp and the Mont Catogne (see later) and that any manifestation of eruptivity at any of those places pertains to the magma during or comparatively soon after its unconsolidated state which subsequently produced the solidified eruptive rocks of the Central zone. Volcanic eruptions as a rule cause ashes and/or lavas to be ejected, and the next question to be investigated is therefore : are there such anywhere about ? Alpine geological literature (see (1) and (8*a*)) provides us with the fact that immediately to the north of the Central Granite zone and trending roughly parallel to it, deposits of recent, Tertiary (?) tuffs and lavas, known as the Taveyannaz series are to be found, stretching from the Diablerets to near Vättis (170 km.). Current conception excluding the possibility of any connexion between these volcanic ejecta and the granites in their immediate neighbourhood, caused E. Argand and R. Staub simultaneously to emit the idea, it would seem, that these ejecta originated from the Bergeller region, the former later on changing his views on the subject in so far that he considered their origin from the Biella-Travestella region as more likely. Heim summarizes the present views on the question as follows (4, vol. ii, pt. ii, p. 587) : "The

Taveyannaz rocks are partly diabasic and andesitic flows, partly their associated tuffs intercalated in the Oligocene (Lattorfien). The material must therefore originate from a Tertiary Oligocene volcano. Tertiary eruptives are however unknown in the Swiss Alps and their neighbourhood except for the Bergeller massive. The Bergeller massive and its associates therefore represent the profoundly denuded, solidified magma chambers of the Taveyannaz volcanoes, so long looked for, and the Taveyannaz rocks the eruptive facies (lava and ashes) of the Bergeller tonalites and granites . . . We also consider this surmise regarding the origin of the Taveyannaz rocks as an extremely probable solution . . . although there remain some contradictory facts with regard to certain phenomena still to be solved (i.e. local interfolding of these ejecta with Eocene strata)."

Apart from other considerations we may register as acquired, duly established facts, that the Taveyannaz series represent volcanic ejecta, *ashes and lavas*, erupted in the Oligocene or more recent times, i.e. in the Alpine orogenetic period.

Now besides the difficulty mentioned by Heim (which is inherent in current conceptions of orogenesis) there is another connected with the proffered solution of the Taveyannaz problem which jumps to the eye when looking at the sketch-map given below (Fig. 2). The question is forced upon one, how it is possible to account, were the Argand-Staub contention admissible, for the obvious facts (*a*) that these deposits are wanting in the vast region between their supposed points of emanation and the zone of their actual occurrence; (*b*) that they are so intimately attached to the zone of the "Hercynian" granites along which they are arranged in parallel; and (*c*) that volcanic ejecta, *tuffs and lavas*, could get accumulated to such powerful deposits at distances away from their points of emanation varying from about 100 km. to nearly double that distance!

It is clear that every one and all of these questions refute the admissibility of the Argand-Staub interpretation of the origin of these volcanic ejecta. On the other hand the presence of these emanation-products at the very foot of the Diablerets Volcano supplies conclusive corroborative evidence on the historically established fact of its eruption.

When searching for other points from which these volcanic products may have emanated it seems therefore rational to study this very zone of Taveyannaz tuffs and lavas, instead of looking for them a hundred or more kilometres away. Two of these I can indicate already almost with certainty.

In fact the eruptions of the Diablerets and the Cirque de Luan are not only recorded in documents of the period, *they also originated traditions which are still alive among the local inhabitants of the two regions concerned.*

In substance they are remarkably alike, reminding one forcibly

SUMMIT OF MT. CATOGNE IN WINTER.

To face p. 477.]

of the Biblical tale of the destruction of Sodom and Gomorrah and describing in a primitive way the outburst of a volcano. In these cases tradition is consequently verified by historical documentary evidence, which is not the case with regard to two other traditions, *substantially identical* and current about the *Blümlisalp* (11, 12) and the *Mont Catogne* (9, 10, 11, 12). As for the Blümlisalp, the Tertiary tuffs and lavas, the Taveyannaz series, are there again at its very foot and strongly developed, to corroborate the tale of tradition. As for the Mont Catogne, these recent ejecta have not yet been established

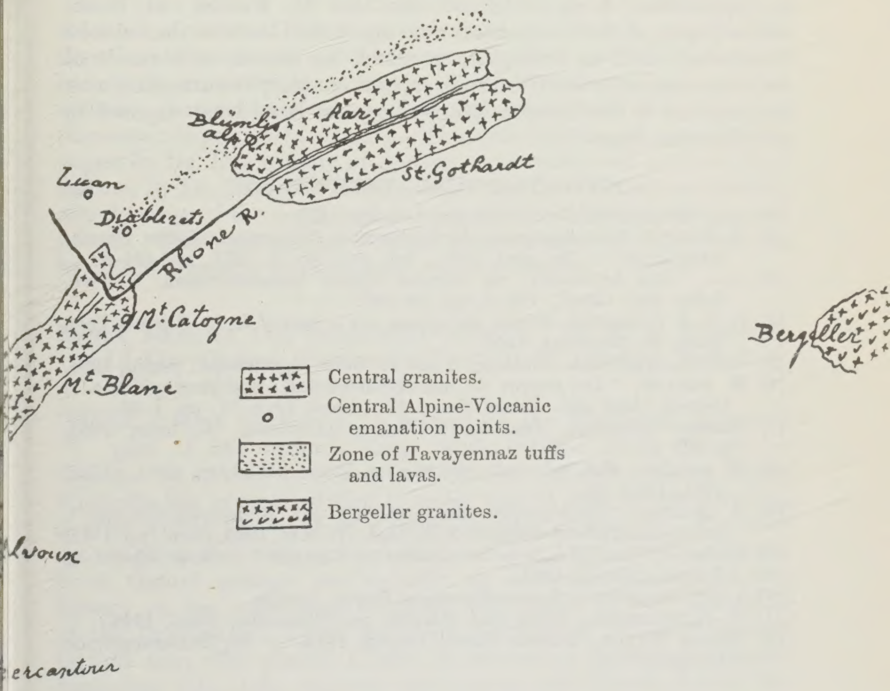

Fig. 2.—Rough sketch showing trend of central, so-called "Hercynian" Granites and relative positions of the Taveyannaz tuffs and lavas, the central Alpine volcanoes and Bergeller eruptive region.

in its immediate neighbourhood (nearest deposit of Taveyannaz sandstones about 29 km. to the north), as it seems. Yet its form is strongly suggestive of that of a volcano and its summit is like a typical crater; it consists of a felsitic porphyry. (Plate XXVIII.)

Summarizing, we may conclude that the facts above detailed all converge to prove again our contention regarding the age of the Western Alpine Central Granites, in the very zone of which we can indicate the sites of four emanation points of volcanic activity, with their recent products still lying at their feet or in their close vicinity. All these facts now not only decide the long-contested question about the age of the Central Granites in favour of the contention sustained by E. Weinschenk and the writer, but also lead to another equally certain conclusion: that the metamorphism in the Alps, including its facies of so-called "basic intrusions" (the feeding channels of which are admittedly untraceable) is of magmatic origin.

In conclusion, I may state that when this paper was ready for publication, I was informed that Dr. M. Richter, of Bonn, read a paper, at the last general meeting of the Deutsche Geologische Gesellschaft held at Stuttgart, in which he stated, as a result of elaborate studies in the Western Alps, that contrary to current opinion the granites of the Central Massives cannot have been exposed in pre-Oligocene times.

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(8*a*) J. Krebs, "Geologische Beschreibung der Blümlisalp-Gruppe": *Beitr. geol. Karte. d. Schweiz,* N.F., Lief. III. Abt. 1925, Bern., pp. 1–75.

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REVIEWS.

ÜBERSICHT ÜBER DIE NUTZBAREN BODENSCHÄTZE SPANIENS. By F. SCHUMACHER. Beiheft zur *Internationalen Bergwirtschaft*, pp. 109, with figures and a folding map. Leipzig, Hirschfeld, 1926.

THE meeting of the International Geological Congress in Madrid afforded an obvious opportunity for the publication of a work of this kind. Since, however, the Iberian peninsula forms so well-defined a geological unit, it is rather a pity that the mineral deposits of Portugal were not also included, for the sake of completeness. The greater part of the book, written by Dr. Schumacher, gives a readable account of the more important of the rich metalliferous deposits of Spain, with special reference to their geological character and their relations to structure, earth-movements, and igneous activity. Incidentally, a very clear account is given of the tectonic elements composing the country. The second section of twenty-three pages, by Dr. Dannenberg of Aachen, deals with coal, and the third section, by Dr. Harbort of Berlin, describes the extremely interesting salt deposits of the north-east, which, as is well-known, carry much potash. The book can be strongly recommended to those desiring to obtain a general acquaintance with its subject.

EARLY MEDICAL AND BIOLOGICAL SCIENCE. By R. T. GUNTHER, LL.D. Oxford University Press; and London, Humphrey Milford, 1926. Price 7*s.* 6*d.* net.

THIS volume consists of a reprint of the fourth or biological part of the author's larger work entitled *Early Science in Oxford.* It is now re-issued without the expensive plates which illustrate the original edition in order that it may be produced at a price within the reach of a larger number of readers. The first six chapters deal with early medicine and biology, but the seventh is on Oxford geology and includes an admirable account of the history of the collections of rocks and fossils in the possession of the University. There are short biographies of the numerous Oxford men who played a part in advancing geological science, beginning with John Aubrey, who shares with Martin Lister the first conception of a geological map, and passing on to Hooke, the author of *Discourses on Earthquakes,* Plot who wrote the first and best *Natural History of Oxfordshire,* with figures of a hundred fossils, Lhwyd, who described both fossils and minerals, Pennant, the well-known zoologist, and other less known men of science. There is a review of the great work of William Smith, whose association with Oxford consisted of his having been born in the county and done his first work there. Some ten pages are devoted to Dean Buckland, one who in spite of much antagonism in the University exerted a remarkable influence on contemporary scientific thought, both at Oxford and elsewhere. The review concludes with brief references to the earliest of the moderns, Scrope and Lyell. The whole work is a mine of interest for the scientific historian. It is illustrated by many curious figures reproduced from the books and memoirs with which it deals.

F. H. A. M.

THE GEOLOGY OF THE COUNTRY AROUND STOKE-UPON-TRENT. By WALCOT GIBSON, D.Sc., F.R.S., with contributions by C. B. WEDD, B.A., and A. SCOTT, M.A., D.Sc. Mem. Geol. Survey, Expl. Sheet 123. Third edition, pp. 122, with 2 plates and 15 text-figures. Price 2*s*. 6*d*. net.

IT is now twenty-four years since the first edition of this memoir was published and the field work in other coalfields in the Midland Counties during the interval has clearly demonstrated the great value of the survey of the Pottery Coalfield by Dr. Gibson and his assistants, and confirmed the main conclusions then reached. That work led to two important developments. In the first place the " Permian " of Hull's earlier map of the area was for the first time subdivided, and the Keele Beds grouped with the Coal Measures, with the happiest results locally, since it helped to bring out with clearness the tectonics of the coalfield, and to indicate with greater precision the extent and depth of the buried fringe of Coal Measures to the south. In the second place, the new one-inch geological map which the memoir described was the first of the series to be colour-printed.

Perhaps there is no geological map issued by the Geological Survey which has proved so useful and instructive in class-teaching as Sheet 123, which is explained by this memoir. Within its compass there are excellent illustrations of pitching folds, faults, unconformities, outliers, and such like, and the much less cost of the colour-printed, as compared with the hand-coloured, map made it possible for the first time for all students to use a copy of the published map.

In the present edition of the memoir the information in respect of new developments has been brought up to date. A valuable addition has been made in the chapter on the Intrusive Igneous Rocks of North Staffordshire by Dr. A. Scott. It contains a very clear and able account of the field relations and petrography of the Butterton Dyke and other intrusives, with explanatory text-figures and micro-photographs, as well as chemical analyses. The author confirms the post-Triassic age of these intrusives, and shows that petrographically, and possibly in geological age, they are allied to the early Cainozoic dyke rocks of Scotland.

May we enter a protest against the objectionable practice of the publishers in sending these memoirs with flexible covers folded down the middle, to the detriment of the volume and especially the contained plates.

W. S. B.